PERFORMANCE OF DIFFERENT HERBICIDES TO CONTROL WEED IN AROMATIC RICE

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PERFORMANCE OF DIFFERENT HERBICIDES TO CONTROL WEED IN AROMATIC RICE

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CERTIFICATE

*This is to certify that thesis entitled, "**PERFORMANCE OF DIFFERENT HERBICIDES TO CONTROL WEED IN AROMATIC RICE**" submitted to the Faculty of Agriculture, Sher-e-Bangla Agricultural University, Dhaka, in partial fulfilment of the requirements for the degree of **MASTER OF SCIENCE (M.S.) in AGRONOMY**, embodies the result of a piece of bona-fide research work carried out by **MEHNAJ SAMANTA LUCKY**, Registration no. **13-05493** under my supervision and guidance. No part of the thesis has been submitted for any other degree or diploma.*

I further certify that such help or source of information, as has been availed of during the course of this investigation has duly been acknowledged.

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ABSTRACT

The field experiment was conducted in the Agronomy field, Sher-e-Bangla Agricultural University ($90^0$33´ E longitude and $23^0$77´ N longitude), Dhaka, Bangladesh, during July to December, 2018 with a view to find out the performance of aromatic rice as affected by different herbicidal weed control method. The experiment consisted of 2 factors, Factor A: Herbicide-4 *viz.*, H_0 – Control (No herbicide used, no weeding), H_1 – Pyrazosulfuron ethyl 70% WG @ 15 g ha^{-1}, H_2 – Bensulfuron methyl 10% WP @ 50 g $ha^{-1}$and H_3 – Metsulfuron methyl 20% WP @ 20 g ha^{-1} and factor B: variety-3 *viz.*, V_1 - BRRI dhan38, V_2 - BRRI dhan70 and V_3 - BRRI dhan80. The experiment was laid out in split plot design with three replications assigning herbicidal weed control in main plot and variety in sub plot. The results revealed that twenty-five weed species infested the total experimental field, which belongs to twelve different families. The most important weeds of the experimental plots were *Cyperus michelianus, Echinochloa crussgalli, Cyperus esculentus, Sagittaria guyanensis, Alternanthera sessilis, Cyperus difformis, Sphenoclea zeylanica* and *Ludwigia octovalvis* respectively. The result also revealed that the application of Metsulfuron methyl 20% WP @ 20 g ha^{-1} (H_3) treatment gave the lowest weed density and dry matter content of weed and highest grain yield which attributed to higher number of effective tiller $hill^{-1}$(13.54), number of filled grains $panicle^{-1}$(92.78), weight of 1000 grain (23.09 g). Considering variety, BRRI dhan70 produced highest grain yield (5.21 t ha^{-1}), biological yield (10.44 t ha^{-1}) and harvest index (49.81 %) which may be due to higher effective tiller $hill^{-1}$ (13.54), number of filled grain $panicle^{-1}$ (84.25), weight of 1000 grains (23.80 g) in this variety. On the other hand, interaction of H_3V_2 (Metsulfuron methyl 20% WP @ 20 g ha^{-1} with BRRI dhan70) treatment gave the highest grain yield (5.65 t ha^{-1}) which may perhaps the highest number of effective tillers $hill^{-1}$ (16.80), total tillers $hill^{-1}$ (18.06), panicle length (34.81 cm), number of filled grains $panicle^{-1}$ (98.46), weight of 1000-grains (26.97 g), biological yield (11.05 t ha^{-1}) and harvest index (51.13 %) in this interaction. It may be concluded that application of Metsulfuron methyl 20% WP @ 20 g ha^{-1} is an effective weed controlling herbicide for the maximum grain production of BRRI dhan70.

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CHAPTER I

INTRODUCTION

Rice (*Oryza sativa* L.) is one of the most important staple food crops, which supplies a major source of calories for above 45% of the world population particularly to the people of Asian countries. Rice stands second in the world after wheat in area and population. It occupies an area of 153.76 m. ha with an annual production of 598.85 MT with a productivity of 4895 kg ha^{-1} in the world (FAO, 2017). Asia produces and consumes 90% of the world's rice. Among the rice growing countries, India ranks the 1st in the area following by China and Bangladesh (FAO, 2018).

Rice is the most important cereal crop in Bangladesh and it is our staple food which covers 92% of food grain production. Approximately 75% of the total cultivated land covering about 11.58 million ha produces approximately 30 million tons of rice annually (BBS, 2018). The 2nd largest part of the total production of rice comes from Aman rice after Boro. Agriculture in Bangladesh is characterized by intensive crop production with a rice-based cropping system. The average yield of rice in our country is around 4.57 t ha^{-1} which is less than the world average (7.48 t ha^{-1}) and frustratingly below the highest yield recorded (9.65 t ha^{-1}) in Australia (FAO, 2019).

In Bangladesh, three distinct classes of rice, based on the season of cultivation namely Aus, Aman and Boro are cultivated during the period April to July, August to December, and January to May, respectively. On average, Aus, aman, and Boro rice were recently reported to account for 7%, 38%, and 55%, respectively, of the total rice production in Bangladesh (Risingbd, 2014). Among three growing seasons, Aman rice occupies the highest area coverage (34% of gross cropping area). There are 47 aman rice varieties cultivated in Bangladesh including aromatic, non-aromatic, hybrid, and HYV rice (BRRI, 2018).

More than four thousand wild races of rice are adapted in our country. Some of these have some good qualities i.e., taste, aroma, fineness, and protein content (Kaul *et al.*, 1982). Aromatic rice is a special type of rice containing the natural ingredient 2-acetyl−1-pyrroline, responsible for their fragrant taste and aroma (Hossain *et al.*, 2008; Gnanavel and Anbhazhagan, 2010) and had 15 times more 2-acetyl−1-pyrroline content than non - aromatic rice (0.14 and 0.009 ppm, respectively) (Singh *et al.*, 2000). In addition, there are about 100 other volatile compounds, including 13 hydrocarbons, 14 acids, 13 alcohols, 16 aldehydes, 14 ketones, 8 esters, 5 phenols, and some other compounds, which are associated with the aroma development in rice (Singh *et al.*, 2000). Most of the aromatic rice varieties in Bangladesh are traditional photoperiod sensitive types and are grown during aman season. Demand for aromatic rice in recent years has increased mainly for both internal consumption and export (Singh *et al.*, 2000). Aromatic rice varieties are rated best in quality and fetch a much higher price than non-aromatic rice.

Weeds grow in crop fields throughout the world. It is often said, "Crop production is a fight against weeds" (Mukhopadhyay and Ghosh, 1981). The prevailing climatic and edaphic conditions are highly favorable for the luxuriant growth of numerous species of weeds, which offer a keen competition with rice crops. Since weeds and crops largely use the same resources for their growth, they will compete when these resources are limited (Zimdahl, 1980). Weeds in tropical zones cause yield loss on rice of about 35% (Oerke and Dehne, 2004). Most of the weeds derive their nourishment through rapid development and manifested by quick root and shoot development. Uncontrolled weeds cause grain yield reduction up to 76% under transplanted conditions in India (Singh *et al*., 2004 b). Weeds are the most competitors in their early growth stages than the later and hence the growth of crops slows down and grain yield decreases (Jacob and Syriac, 2005).

In a rice field, a variety of weeds grown are generally classified into three groups namely, grasses, sedges, and broadleaf weeds according to their morphological

character. Weed infestation and interference is a serious problem in rice fields that significantly decreases yield. Weed management plays an essential role in crop production having a great influence on growth, yield and yield contributing characters of transplanted aman rice. Weed depends on the availability of water supply, soil texture and structure, location of the field, weather and climatic condition of the field, depth of plough pan and organic matter content of soil (Hossen *et al.*, 2015). Without weed control, yield losses have been estimated 16 to 48% in transplant aman rice (Alam *et al.*, 1996).

In Bangladesh, the traditional methods of weed control practices include preparatory land tillage, hand weeding by hoe and hand pulling. Usually, two or three hand weeding is normally done for growing a rice crop depending upon the nature of weeds, their intensity of infestation and the crop grown. Weed control in transplant *aman* rice by mechanical and cultural methods is expensive (Mitra *et al.*, 2005). In contrast, chemical weed control is easier and cheaper. On the other hand, chemical methods lead to environmental pollution and negative impact on public health (Phuhong *et al.*, 2005). In large-scale production, herbicide-based weed management has become the smartest and most viable option as scarcity and high cost of labour (Anower *et al.*, 2012). Therefore, the vegetation community consisting of rice crops and weeds should be seen and regarded as a competitive and cooperative system that has to be managed appropriately.

Based on the facts, the present study was undertaken with the following objectives:

1. Evaluate the weed control efficiency of different herbicides in aromatic rice,
2. Find out the effect of variety on the growth and yield of aromatic rice with different herbicides, and
3. To investigate the interaction effect of aromatic rice variety and different herbicides on yield component and yield of aromatic rice.

CHAPTER II

REVIEW OF LITERATURE

Control of weed is one of the important factors for successful crop production. Weed control by herbicides is a common practice in many countries of the world as well as Bangladesh due to its competitive advantages over other methods. However, research work in the field of weed science especially with herbicides is scanty in Bangladesh. Although some sporadic research works have been done on herbicides intensive research works have not been evaluated under different conditions in Bangladesh for controlling weeds in rice fields especially with aromatic rice. Research works at Bangladesh and abroad in controlling weeds in rice fields using different herbicides are reviewed below:

2.1 Effect of different herbicides on weed infestation in the aromatic rice field

Moonmoon (2015) conducted a field experiment to find out the herbicidal efficacy and residual activity on transplanted aromatic Boro rice (cv. BRRI Dhan50) using nine treatments, *viz*., T_0: (control), T_1: Acetochlor + Bensulfuron-methyl (changer) [750 g ha^{-1}], T_2: Pyrazosulfuron-ethyl (super powder) 150 g ha^{-1}. T_3: Bispyribac sodium (extra power) 150 g ha^{-1}, T_4: Pretilachlor (superhit) 1 L ha^{-1}. T_5: Pretilachlor + Triasulfuron (Rifit + logran) 1 L ha^{-1} + 10 g ha^{-1}, T_6: Propyrisulfuran+ Propanil [500 ml ha^{-1} +1000 g ha^{-1}], T_7: Propyrisulfuran + Propanil [380 ml ha^{-1} +1500 g ha^{-1}], T_8: Two hand weeding at 20 DAT and 40 DAT. The highest weed control efficacy (98.74%) was recorded from Propyrisulfuran + Propanil [380 ml ha^{-1} +1500 g ha^{-1}] treatment and its residual activity remained up to 45 days. It had checked seven weed species including the dominating weed Behua (*Cyperus difformis*) from the rice field. On the other hand, the highest weed infestation and yield loss (44.09%) were recorded in the control treatment.

Hossen (2014) carried out a field experiment to find out the effect of three sources of Nitrogen viz. control, Prilled urea (PU) and USG (Urea Super

Granule) and three weed control treatment viz. control, two hand weeding, and pre-emergence herbicide Rifit 20EC on growth, yield and yield components of Kalijira, BRRI dhan37 and BRRI dhan38 transplant aromatic T. aman rice. Pre-emergence herbicide Rifit 20EC was applied at 5 DAT. Rifit 20EC applied plot gave the highest grain yield (3.23 t ha^{-1}) while no weeding had the lowest plant height, numbers of total tiller $hill^{-1}$, CGR and total dry matter. Interaction results showed that significantly higher grain yields were given by PU × BRRI dhan38 (3.50 t ha^{-1}), USG × BRRI dhan38 (3.82 t ha^{-1}) and on the other hand, Rifit 20EC × BRRI dhan38 (3.71 t ha^{-1}) and interaction of USG × BRRI dhan38 × Rifit 20EC (4.28 t ha^{-1}).

Chowdhury (2012) set up a field experiment in aman season with a view to find out the performance of transplant aromatic rice varieties under different weed control methods. The experiment was carried out with four varieties *i.e.*, BRRI dhan34, BRRI dhan37, BRRI dhan50 and Chinigura in the main plot and five weed management methods *viz.*, control (no weeding), one hand weeding at 15 DAT, two hand weeding 15 DAT + 40 DAT, Topstar 400SC (Oxadiargyl 400 g L^{-1}) @ 100 g ha^{-1} as post-emergence and Sunrice 150WG (Ethoxysulfuron 150 g kg^{-1}) @ 185 ml ha^{-1} as pre-emergence herbicide in the sub plot in split-plot design. The interaction effect showed that BRRI dhan34 in combination with Sunrice 150WG produced the highest grain yield (4.10 t ha^{-1}) while the lowest grain yield (1.44 t ha^{-1}) was obtained from BRRI dhan50 in control treatment.

Gnanavel and Anbhazhagan (2010) conducted a field experiment to study the bio-efficacy of promising pre- and post-emergence herbicides against weeds in transplanted aromatic basmati rice. They concluded that pre-emergence application of oxyfluorfen 0.25 kg ha^{-1} followed by post-emergence application of bispyribac sodium 0.05 kg + metsulfuron-methyl @ 0.01 kg ha^{-1} recorded the highest WCE (90.12%) favouring higher grain yield of aromatic rice (5.32 t ha^{-1}).

2.2 Effect of herbicides on growth and yield attributing characters

2.2.1 Plant height

Hasanuzzaman *et al.* (2008) stated that Ronstar 25EC @ 1.25 L ha^{-1} + IR5878 50WP @ 120 g ha^{-1} was the most efficient that influenced plant height according to the effectiveness of the treatments.

2.2.2 Total dry matter production

Bhuiyan *et al*. (2011 b) conducted a field experiment to evaluate the performance of different weed management options regarding effective weed control, yield and yield contributing characters of three popular BRRI aman varieties having different growth duration (BRRI dhan39, BRRI dhan49 and BR11). The researcher reported that total dry matter was significantly the highest in plots which received three hand weeding at 15, 30 & 45 DAT (20.17 g m^{-2}) and post-emergence herbicide + 1 hand weeding at 30 DAT (22.20 g m^{-2}).

Ali *et al.* (2008) conducted an experiment to observe the effect of integrated weed management and spacing on the weed flora and on the growth of transplanted aman rice. The weeding treatments were - no weeding, two hand weeding at 15 and 40 days after transplanting (DAT), one weeding with BRRI push weeder at 15 DAT + one hand weeding at 40 DAT, pre-emergence application of M.Chlor 5G (Butachlor) at 5 DAT + one hand weeding at 40 DAT, pre-emergence application of Oxastar 25 EC (Oxadiazon) at 5 DAT + one hand weeding at 40 DAT, pre-emergence application of Rifit 500EC (Pretilachlor) at 5 DAT + one hand weeding at 40 DAT and three plant spacing's viz. 20cm × 10cm, 25cm × 15cm and 30cm × 20cm. It was evident that among the weed control treatments, Pretilachlor + one hand weeding gave the highest crop growth rate (0.71 g $hill^{-1}day^{-1}$) at 45−60 DAT.

BRRI (1998) reported that Cinosulfuron and Oxadiazon showed better performance than Butachlor in terms of biomass and plant population and also

stated that two hand weeding gave the highest weeding cost of herbicide treatment.

2.2.3 Effective tillers hill^{-1}

Hasanuzzaman *et al.* (2008) discribed that Ronstar 25EC @ 1.25 L ha^{-1} + IR5878 50 WP @ 120 g ha^{-1} was the most efficient for the number of effective tillers hill^{-1} according to the effectiveness of the treatments.

Kumar and Uthayakumar (2005) conducted a field experiment to study the effect of sequential application of pre- and post-emergence herbicides and possibility of weed management with and without herbicides in wet seeded rice. They used one hand weeding at 25 DAT, Butachlor @ 1 kg ha^{-1} at 8 DAT, 2,4-D @ 0.5 kg ha^{-1} at 25 DAT, two hand weeding at 25 and 50 DAT and unweeded control. Among the treatments, butachlor had significant effect on weed population and grain yield of rice. This was reflected in increased number of productive tillers hill^{-1} and finally grain yield of rice. The other weed control practices produced similar effect except unweeded control.

Raju *et al.* (2003) observed the effect of pre-emergence application of Pretilachlor plus Safener 0.3 kg ha^{-1}, Butachlor 1 kg ha^{-1} and post-emergence herbicide like Butanil 3.0 kg ha^{-1} on 4, 8 and 15 days after sowing. They found that Pretilachlor plus Safener 0.3 kg ha^{-1} gave the highest productive tillers m^{-2}.

Haque (1993) assessed the efficiency of Oxadiazon in transplanted aman rice and observed that Oxadiazon 2.0 Litre ha^{-1} gave maximum effective tillers hill^{-1}.

2.2.4 Effect of herbicides on yield and yield components of rice

Singh *et al.* (2014) carried out an experiment to evaluate the performance of transplanted rice under pre-emergence herbicides and hand weeding techniques. The treatment consists of seven weed management techniques viz., W_1 = Butachlor @ 1.5 kg ai ha^{-1}, W_2 = Butachlor @ 1.0 kg ai ha^{-1} + 2,4 D @ 1.0 kg ai ha^{-1}, W_3 = Bensulfuron methyl 0.6% + Pretilachlor 6% G @ 10.0 kg ha^{-1}, W_4 = Chlorimuron + Metsulfuron-methyl 20 WP @ 4 g ai ha^{-1}, W_5 = Pyrazosulfuron

ethyl @ 30 g ai ha^{-1}, W_6 = Two hand weeding at 25 and 50 days after transplanting and W_7 = Weedy check (control). The highest grain yield (7.2 t ha^{-1}) was obtained from W_6 (two hand weedings) because of reduced dry weight of weeds and higher values of yield components. This was statistically at par with pre-emergence application of Pyrazosulfuronethyl (6.70 t ha^{-1}) and ready mix Chlorimuron + Metsulfuron methyl (6.20 t ha^{-1}). The highest net return (53,950 ha^{-1}) and BCR (2.39) was also obtained with two hand weedings followed by Pyrazosulfuron ethyl and Chlorimuron + Metsulfuron methyl application.

Madhukumar *et al.* (2013) evaluated the relative efficacy of different herbicides for weed control in aerobic rice cultivation system. Among different herbicidal treatments, pre-emergent application of bensulfuron methyl @ 60 g + pretilachlor @ 600 g ha^{-1} recorded significantly higher productive tillers per hill (21.32), panicle weight (2.81 g), 1000-grain weight (21.80 g), filled spikelets per panicle (88.23), weed control efficacy (91.37), grain yield (4100 kg ha^{-1}), straw yield (4961 kg ha^{-1}) and lower total weed density and dry weight (72 No. m^{-2} and 3.65 g 0.25 m^{-2}, respectively), followed by two hand weedings at 20 and 40 DAS and oxyfluorfen @ 90 g ha^{-1} as pre-emergent spray followed by 2, 4-DEE as post-emergent spray @ 500 g ha^{-1} at 25 DAS.

Parvez *et al*. (2013) evaluated the effect of cultivar and weeding regime on the performance of transplant Aman rice. The experiment consisted of two factors namely factor A: cultivar: - BRRI dhan41 and Nizershail; and factor B: weeding regime: - no weeding, one hand weeding at 21 DAT, two hand weeding at 21 and 42 DAT, application of Pretilachlor herbicide, application of Pretilachlor herbicide + one hand weeding at 21 DAT and weed free. The maximum weed growth was noticed with the dwarf cultivar BRRI dhan41 and minimum with taller cultivar Nizershail. Complete weed free treatment resulted in the lowest weed population and weed dry weight followed by application of Pretilachlor herbicide + one hand weeding at 21 DAT treatment. BRRI dhan41 produced the higher grain and straw yields than the cultivar Nizershail. The highest loss of

grain yield was recorded in no weeding treatment and the lowest was recorded in weed free treatment followed by application of Pretilachlor herbicide + one hand weeding at 21 DAT in transplant aman rice (BRRI dhan41). The highest number of effective tillers hill^{-1}, highest number of grains panicle^{-1} and the heaviest 1000-grain weight were observed in weed free treatment followed by application of Pretilachlor herbicide + one hand weeding at 21 DAT treatment.

Pal *et al.* (2012) studied the efficacy of pyrazosulfuron-ethyl against weeds in transplanted rice. They found Pyrazosulfuron-ethyl at 42.0 g ha^{-1} applied at 3 DAT was the most effective in managing associated weed species and returned the maximum grain yield (3.30 t ha^{-1}) of rice with lower weed index (10.80%).

Abbassi *et al.* (2012) evaluated on rice (*Oryza sativa*) general herbicides in intermission flooded conditions and control of weeds including Barnyard grass (*Echinochloa crus-galli*), Sedges (*Juncus*) and Broadleaves. Treatments were: Butachlor 60% EC, Pertilachlor 50% EC, Oxadiargyl 30% EC, Pendimethalin 33% EC, Molinate 72% EC, Thiobencarb 50% EC, Clodinafop-propargyl 8% EC, Fenoxaprop 57% EW, 2,4-D 72% SL, Propanil 36% EC and Bentazone 48% SL at 4, 2, 3.4, 4, 6, 6, 0.6, 1, 2, 15 and 3 L ha^{-1}, respectivly and Cinosulfuron 20% WG at 150 g ha^{-1}. The results indicated that "Pretilachlor + Pretilachlor" treatment showed the best performance based on EWRC standard evaluation and also had 3471 kg ha^{-1} grain yield which was the best output in comparison to other treatments. Also "Thiobencarb + mixed of Bentazone and Propanil", "Oxadiargyl + mixed of Bentazone and Propanil" and "Butachlor + mixed of Bentazone and Propanil" treatments with 3454, 3390 and 3349 kg ha^{-1} yield, respectively had acceptable yield in comparison to three times of hand weeding check treatment with 3044 kg ha^{-1} yield.

Abdul *et al.* (2011) conducted an experiment using three herbicides namely Stomp 455CS (pendimethalin) at 1650 g a.i. ha^{-1} as pre-emergence, Nominee 100SC (bis-pyribac sodium) and Ryzelan 240SC (penoxsulam) at 30 and 15 g a.i. ha^{-1} respectively, were used as early post-emergence (15 DAS). Maximum paddy yield (2.79 t ha^{-1}) and net benefit of Rs. 83712 ha^{-1} were recorded where

pendimethalin was followed by penoxsulam. Results indicated that pendimethalin followed by post emergence application of bispyribac sodium and penoxsulam gave more than 80% reduction in weed density and weed dry weight over control. Moreover, sequential applications of herbicides were better than alone in dry seeded rice.

Al-Mamun *et al.* (2011) carried out an experiment on Surjamoni and BRRI dhan29 and observed that the highest grain yield (6.96 t ha^{-1}) was obtained from Surjamoni when treated with Bouncer 10WP @ 150 g ha^{-1}, which was 49% higher than control. BRRI dhan29 produced the highest grain yield when treated with same treatment, which was 37% higher than control.

Bhuiyan *et al.* (2011 a) conducted field experiments during dry season (Boro) to assess the effectiveness of different pre-emergence herbicide for weed management in direct wet seeded rice and its impact on phytotoxic effect, plant growth and yield of rice. They found that pre-emergence application of Sofit N 300EC @ 450 and 600 g a.i. ha^{-1} led to higher yield attributes and grain yield of rice that were comparable to weed free conditions at both agro-ecological zones of Bangladesh.

Khaliq *et al.* (2011) reported that manual weeding produced the highest paddy yield of 4.17 t ha^{-1} whereas, Bispyribac sodium with 3.51 t ha^{-1} paddy yield appeared superior to penoxsulam. Sorghum, sunflower and wheat residues resulted in statistically similar paddy yields of 2.85, 2.80 and 2.58 t ha^{-1}, respectively. Bispyribac sodium exhibited maximum marginal rate of return of 23.76%. Chemical control method for weed proved to be a viable strategy with higher economic returns.

Mamun *et al.* (2011 c) conducted field experiments to evaluate the performance of Bensulfuron methyl + Pretilachlor 6.6% GR for weed suppression and its impacts on transplanted rice. They observed that application of Bensulfuron methyl + Pretilachlor 6.6% GR @ 652 g a.i. ha^{-1} resulted in higher yield attributes and grain yield of transplanted rice that were comparable to the standard value.

Mamun *et al*. (2011 a) evaluated the performance of Acetochlor 50% EC for weed suppression, finding out an appropriate dose of the herbicide and its impacts on transplanted rice. Acetochlor 50% EC @ 200, 250- and 300-ml ha^{-1} were applied. Pretilachlor 50% EC@ 1 L ha^{-1}, weed free and unweeded control was used for comparison. The most dominant weeds were *Cyperus diffornis, Monochoria vaginalis* and *Echinochloa crus-galli* in year 1 and *Cyperus diffformis* and *Echinochloa crus-galli* in year 2. *Cyperus diffformis* was at the higher rank of dominance in both years. Application of Acetochlor 50% EC @ 250 ml gave more than 80% weed control efficiency, lower number and dry weight of weeds which ultimately resulted in higher yield attributes and grain yield of transplanted rice that were comparable to the standard in both seasons.

Mamun *et al.* (2011b) stated that the highest grain yield (6.96 t ha^{-1}) was obtained from Surjamoni when treated with Bouncer 10 WP @ 150 g ha^{-1}, which was 49% higher than control. BRRI dhan29 produced the highest grain yield (5.92 t ha^{-1}) when treated with same treatment which was 37% higher than control.

Shultana *et al.* (2011) conducted an experiment to evaluate the weed control efficiency of some pre-emergence herbicides in transplanted rice and found that among the evaluated herbicides, Rigid 50 EC (pretilachlor) @ 1 L, Alert 18WP (bensulfuron + acetachlor) @ 400 g, Kildor 5G (butachlor) @ 25 kg, Bigboss 500EC (pretilachlor) @ 1 L, Rifit 500EC (pretilachlor) @ 1 L, Ravchlor 5G (butachlor) @ 25 kg, Succour 50EC (pretilachlor) @ 1 L and Topstar 80WP (oxadiazon) @ 75 g ha^{-1} showed grain yields above 4.00 t ha^{-1} which were comparable to the standard check; however, weed free plots gave the highest grain yield as anticipated.

Ali *et al.* (2010) conducted an experiment to evaluate weed control methods and yield of transplanted aman rice (cv. BRRI dhan37) as affected by integrated weed management and spacing. The researchers observed that among the weed control treatments, Pretilachlor + one hand weeding at 40 DAT performed the best for

controlling weeds which ultimately contributed to the highest grain yield (3.60 t ha^{-1}).

Bari (2010) conducted an experiment using eight herbicides, i.e., Oxadiazone, Butachlor, Pretilachlor and Anilphos from pre-emergence, and MCPA, Ethoxysulfuran, Pyrazosulfuran-Ethyl and Oxadiarzil from post-emergence category in transplanted wetland rice during aman (autumn), aus (summer) and boro (winter) growing seasons to study their effects on weed control and rice yield. They observed that the highest grain yield of 4.18 t ha^{-1} was contributed by weed free treatment, while the least (2.44 t ha^{-1}) was by weedy check. Among the herbicidal treatments, the highest grain yield of 4.08 t ha^{-1} was obtained from Butachlor, while the lowest (2.83 t ha^{-1}) grain production was harvested in the plots receiving MCPA @ 125% of the recommended rate. Results further revealed a positive relationship between Butachlor rate and grain yield, although a declining trend was apparent at higher than the recommended rates, while a negative relationship was found in MCPA treatments.

Bhuiyan *et al.* (2010) carried out an experiment during boro season for the control of mixed weed flora in transplanted rice (*Oryza sativa L.*) and stated that among different treatments, weed free plots produced the highest grain yield followed by Oxadiargyl 400SC @ 75 g a.i. ha^{-1} which was comparable with other doses of Oxadiargyl 400SC.

Islam *et al.* (2010) described that pre-emergence herbicide Rifit 500 EC showed the best performance in achieving comparatively better grain yield. As a result, net income was also increased. The highest grain yield (3.61 t ha^{-1}) was obtained from Rifit 500 EC. BRRI dhan41 gave the highest grain yield (4.43 t ha^{-1}) with Rifit 25 EC @ 1.0 L ha^{-1}.

Salam *et al.* (2010) directed a field experiment to evaluate the effect of herbicide on growth and yield in boro rice (Binadhan-5). The highest grain yield (7.15 t ha^{-1}) and straw yield (7.37 t ha^{-1}) were recorded from the application of Machete 5G @ 25 kg ha^{-1}.

Pacanoski and Glatkova (2009) conducted an experiment on the use of herbicides for weed control in direct wet-seeded rice (*Oryza sativa L.*) in rice production regions in the Republic of Macedonia and observed that weed population in the trials was composed of 8 and 5 weed species in Kocani and Probistip locality, respectively. All applied herbicides showed high selectivity to rice, no visual injuries were determined at any rates in any year and locality. Herbicidal treatments in both localities significantly increased rice grain yield in comparison with untreated control.

Kabir *et al.* (2008) revealed that the highest grain yield (5.22 t ha^{-1}) was obtained under good water management in weed free treatment followed by Butachlor 5G @ 2 kg ha^{-1} and one hand weeding (4.96 t ha^{-1}) under same water management. Butachlor application along with one manual weeding accompanied by proper water management might be the best option to combat weed problems as well as to obtain satisfactory grain yield in transplanted aman rice.

Baloch *et al.* (2006) set up an experiment to evaluate the effect of weed control practices on the productivity of transplanted rice. Among weed management tools, the maximum paddy yield was obtained with hand weeding, closely followed by Butachlor (Machete 60EC).

Dhiman (2006) reported the efficacy of various combination of 2,4-D axilofos and chlorinuron in controlling weed infestation in transplanted rice field. Application of 500 g 2,4-D ha^{-1} in combination with chlorinuron resulted in the highest control of grasses, sedges and broadleaved weeds and produced to the tallest plants, highest number of effective tillers $hill^{-1}$ and maximum grain yield (5.83 t ha^{-1}).

Khan and Ashraf (2006) observed that use of Ronstar 25EC gave the maximum grain yield (5.65 t ha^{-1}).

Dhiman and Singh (2005) conducted an experiment to evaluate the effects of low doses of herbicides on weeds, nutrient uptake and yield of transplanted rice. The treatments were 2,4-D @ 500 g ha^{-1}, anilofos @ 400 g ha^{-1}, hand weeding at 20,

40 and 60 days after transplanting and weedy control. Pre-emergence applications of 2,4-D recorded the lowest weed density and biomass among the herbicidal treatments. 2,4-D and hand weeding significantly influenced nutrient uptake by the crop and gave the highest grain yields. The lowest uptake was recorded in weedy control. 2,4-D registered 88% and 83% higher grain yield in the year of 2001 and 2002, respectively, compared with the weedy control.

Jacob and Syriac (2005) showed that adoption of 20 cm × 10 cm spacing and pre-emergence application of Anilofos + 2, 4-D ethyl ester (0.40 + 0.53 kg a.i. ha^{-1}) at six days after transplanting supplemented with 2, 4-D Na salt (1.0 kg a.i. ha^{-1}) at 20 days after transplanting generally favoured increased yield and net income.

Mitra *et al.* (2005) suggested two times weeding as the best practice to keep weed infestation at minimum level and to ensure higher yield in transplanted aman rice. Other than weed free condition, the highest grain yield (5.07 t ha^{-1}) was recorded from two hand weeding and the lowest (2.46 t ha^{-1}) was in unweeded condition. One hand weeding at 25 DAT along with one mechanical weeding at around 40 DAT was also found to be effective next to two hand weeding in these regards. Pre-emergence herbicide Rifit 500EC was not effective to keep weed infestation at minimum level and to ensure higher yield in transplanted aman rice.

Saha (2005) carried out an experiment to compare the efficacy of Butachlor (948 g ha^{-1}) Pretilachlor (500 or 750 g ha^{-1}), Pyrazosulfuron-ethyl (40 or 50 g ha^{-1}), Bensulfuron methyl (40 or 50 g ha^{-1}) + Butachlor (938 g ha^{-1}) and 2 hand weeding (20 and 40 DAT) or 3 hand weeding (20, 40 and 60 DAT) times for controlling weed flora in transplanted rice under rainfed shallow lowland. Results indicated that all treatments significantly reduced weed dry matter and density. The highest grain yield of 5.75 t ha^{-1} was obtained from Pyrazosulfuron-ethyl applied at 40 or 50 g ha^{-1}.

Chandra and Solanki (2003) showed the effect of herbicides on the yield characteristics of direct sown flooded rice. The treatments were two hand

weeding, Butachlor 2.0 kg ha^{-1} and Oxadiazon 0.8 kg ha^{-1}. They found that two hand weeding produced the highest grain yield (3.36 t ha^{-1}) and straw yield (6.53 t ha^{-1}).

Moorthy *et al.* (2002) stated that the application of Pretilachlor @ 625 g ha^{-1} and Butachlor 1600 @ g ha^{-1} on 2 days after sowing and the treatments gave effective weed control and produced the highest grain yield compared with twice hand weeding on 20 and 40 DAT.

Selvam *et al.* (2001) assessed an experiment on the effect of time of seed sowing along with weed management practices in some dry rice. The treatments included sowing practices and herbicide, Pendimethalin 1.24 litre ha^{-1} at 8 days after rainfall (DAR), Pretilachlor 1.0 litre ha^{-1} at 4 DAR and 8 DAR, Pretilachlor + Safener at 4 DAR and 8 DAR, hand weeding twice and unweeded control. All herbicides receiving plots were supplemented with one hand weeding at 25 DAR. Among the herbicides, Pendimethalin recorded the highest grain yield (3773 kg ha^{-1}) and was at par with Pretilachlor at 8 DAR.

Tamilselvan and Budhar (2001) conducted an experiment to see the effects of pre-emergence herbicides Butachlor @ 1.0 kg ha^{-1}, Butanil @ 1.0 kg ha^{-1}, Pretilachlor @ 0.4 kg ha^{-1}, Pretilachlor @ 0.4 kg ha^{-1}, Safener and Anilofos @ 0.3 kg ha^{-1} on rice cv. ADT 43. The herbicides were applied 8 days after sowing. The density and dry weight of weeds at 40 DAS were lower in herbicide treated plots than in unweeded and hand weeded plots. The highest number of productive tillers $hill^{-1}$ was obtained in the plots treated with Anilofos @ 0.3 kg ha^{-1} (14.4), Pretilachlor @ 0.40 kg ha^{-1} (14.2) and Butanil @ 1.0 kg ha^{-1} (13.3). The number of filled grain $panicles^{-1}$ was the highest with Anilofos @ 0.3 kg ha^{-1} (131.7) followed by Pretilochlor @ 0.40 kg ha^{-1} (126.3) and Butanil @ 1.0 kg ha^{-1} (122.1). The weed control treatments were equally effective in increasing grain yield.

Gogoi *et al.* (2000) reported that different weed control practices significantly reduced the dry matter accumulation of weed and increased the rice yield over the unweeded control in transplanted rice. They also observed that combined

weed control treatment like Oxadiazon 2.0 L ha^{-1} + one hand weeding increased grain yield (5.12 t ha^{-1}).

Ganeshwor and Godadhar (2000) conducted a research work to evaluate the effectiveness of herbicides on controlling weeds and improving grain yield in transplanted rice. Herbicides were effective in controlling the weeds at 21 DAT. The 2,4-D amine gave the highest values for grain yield (3.89 t ha^{-1}), total number of spikelets (19.30 m^{-2}), number of grains spikelets^{-1} (18.65), percentage of seed setting (96.60%) and 1000-grain weight (24.69 g).

Hossain (2000) observed experiment-oriented impact of different weeding approaches on rice where one hand weeding, two hand weeding, three hand weeding, Ronstar and Ronstar + hand weeding was used as treatments. He observed that yield and yield contributing characters increased with the increase in frequency of hand weeding.

Moorthy *et al.* (1999) evaluated the effects of the pre-emergence herbicides Pretialchlor + Safener, Butachlor + Safener, Butachlor, Anilofos + Ethoxysulfuron, Thiobencarb and Anilofos for their efficiency to control weeds in direct sown rice under puddled soil condition. They observed that Pretilachlor + Safener (0.40 kg and 0.60 kg ha^{-1}), Butachlor + Safener (1.5 kg ha^{-1}) and Anilofos + Ethoxysulfuron (0.375 + 0.04 kg ha^{-1}) controlled the most dominant weeds (*Cyperus difformis* and *Fimbristylis miliacea*) and produced yields comparable to those with the hand weeded control.

Singh and Kumar (1999) stated that maximum weed dry weight and the lowest grain yield were observed in the unweeded control in the scented rice variety Pusa Basmati-1.

Ahmed *et al*. (1998) conducted an experiment to investigate the effects of weed control on rice yield and its components. Six treatments were included in the study: no weed control, continuous weeding, weed control via herbicidal application and weed removal at 30, 45 and 60 DAT. The highest number of tillers m^{-2} (331) was recorded under continuous weeding followed by weed

control at 30 DAT and herbicide. The highest grain yield (5.14 t ha^{-1}) was recorded in continuous weeding, followed by weed control at 30 DAT and herbicide.

Angiras and Rana (1998) observed that the greatest yield was achieved from the Pretilachlor (0.8 kg ha^{-1}) + two hand weeding in direct seeded puddled sprouted rice field.

BRRI (1998) evaluated a new pre-emergence herbicide Golteer 5G (Butachlor) in transplanted aus rice and results indicated that hand weeding produced a slightly higher grain yield than Golteer application and weed biomass was lower in hand weeded plots followed by Golteer (Butachlor) treated plots.

Gogoi (1998) observed that Anilofos at 0.4 kg ha^{-1} gave significantly higher yield and the yield was not significantly different from the hand weeding at 20 days after transplanting.

Nandal *et al.* (1998) evaluated the performance of herbicide in direct seeded puddled rice during kharif season. They observed that the highest grain yield and gross margin was obtained from the Pretilachlor (1.0 kg ha^{-1}) + two hand weeding.

BRRI (1996) observed that Ronstar @ 12 L (3.0 L ha^{-1} and 2.0 L ha^{-1}) treated plots had significantly higher number of panicles and grain yield of rice compared to two hand weedings while unweeded plots had the highest weed biomass. It also indicated that 2.0 L Ronstar ha^{-1} gave significantly higher grain yield than 3.0 L Ronstar ha^{-1}. Ronstar (2.0 L ha^{-1}) controlled rice weed satisfactorily except *Cynodon dactylon*.

Bhattacharya *et al.* (1996) showed that although the hand weeding treatment gave the highest grain yield, the results indicated that this was laborious, time consuming and costly and hand weeding could be replaced by application of Butachlor at 1.00 kg a.i. ha^{-1}.

Madhu *et al.* (1996) set up a field experiment to evaluate the effectiveness of four herbicides, Pendimethylin, Anilofos, Butachlor/Safener and Oxyfluorfen at 2 application rates during dry and wet seasons in puddled seeded rice field. The results showed that grain and straw yields were higher in the plots treated with Butachlor / Safener @ 1.50 kg ha^{-1}.

Chowdhury *et al.* (1995) found that six different doses of Oxadiazon viz. 0, 1.5, 1.75, 2, 2.25 and 2.50 L ha^{-1} were used to control weeds in rice. They found that Oxadiazon significantly increased the yield of rice irrespective of the doses used. Out of these doses, 2.0 L ha^{-1} was found to be the most effective with respect to grain yield and straw yield.

Mondal and Nandal (1995) observed the efficiency of Rilof H and Rifit as herbicide in comparison to hand weeding in BR11 variety of Aman rice. Plots treated with Rilof H @ 3 L ha^{-1} produced the highest grain yield (6.0 t ha^{-1}) which was identical with the treatments of hand weeding at 21, 38 and 55 DAT and Rifit @ 2 L ha^{-1}. The lower doses of Rilof H @ 1 L ha^{-1} and Rifit @ 1 L ha^{-1} failed to kill the weeds properly. Higher doses of both Rilof H and Rifit had phytotoxic effects on the rice plant. The grain yield reduced 20.30% due to weed infestation.

BRRI (1991) observed that Ronstar @ using of 3.0 L ha^{-1} had significantly improved the number of panicles and grain yield of rice compared to two-hand weeding. It also indicated that 2.0 L Ronstar 25 EC ha^{-1} gave slightly higher grain yield than 3.0 L Ronstar 25 EC ha^{-1}. Ronstar 25 EC @ 2.0 L ha^{-1} controlled rice weeds satisfactorily except *Cynodon dactylon* L.

BRRI (1990) stated that there was no significant difference in rice yield for using Oxadiazon as well as hand weeding. The highest grain yield was obtained from Oxadiazon @ 0.5 kg a.i. ha^{-1}.

Purushotham *et al.* (1990) observed that Oxadiazon (0.5 kg a.i. ha^{-1}) increased the grain and straw yields significantly than two manual weeding at 25 and 45 DAT.

Shivamdiah *et al.* (1987) investigated that Oxadiazon 0.75 kg ha^{-1} + one hand weeding gave significantly higher yield than herbicide alone. They also found that combination of herbicidal treatment and one hand weeding gave higher straw yield.

2.3 Effect of herbicides on weed population and weed control efficiency

Poornima *et al.* (2015) conducted a field experiment to estimate the harvest time residue of Pyrazosulfuron ethyl (a new generation Herbicide) in transplanted rice field in soil, rice grain and straw. The treatments included four different levels of pyrazosulfuron ethyl (15, 20, 25 and 30 g ha^{-1}), butachlor (1.5 kg ha^{-1}), weed free check, unweeded check and hand weeding twice (at 20 and 40 days after transplanting). The results of the experiment revealed a total absence of pyrazosulfuron-ethyl in soil, rice grain and straw, i.e. no detectable residue could be observed.

Zahan *et al.* (2015) carried out a research work to observe the performance of pre- and post-emergence herbicides in rice (*Oryza sativa*) established by Minimum Tillage Unpuddled Transplanting. The results revealed that pyrazosulfuron-ethyl followed by orthosulfamuron and (butachlor + propanil) reduced weed biomass by 96–97% compared to non-treated weedy plots. On the other hand, pyrazosulfuron-ethyl with one post-emergence herbicide either (butachlor + propanil) or 2,4-D reduced weed by 91 to 92 %. Butachlor followed by orthosulfamuron followed by (butachlor + propanil) also reduce weed biomass by 91% compared to non-treated control. Only pyrazosulfuron-ethyl followed by orthosulfamuron and (butachlor + propanil) achieved yields close to those of the weed-free treatments (5.42-6.04 t ha^{-1}). Among the herbicide treatments, sole application of butachlor produced low grain yield similar to the non-treated crop (2.76–3.1 vs 3.13 t ha^{-1}) suggesting low activity of this herbicide on weed control in unpuddled soil. The results suggest that pyrazosulfuron-ethyl was the most effective pre-emergence herbicide in unpuddled transplanting system especially when applied with orthosulfamuron and / or (butachlor + propanil) or 2,4-D as a post-emergence herbicide.

Kumaran *et al.* (2015) revealed that Early Post-Emergence (EPOE) application of Bispyribac sodium 10% SC 40 g ha^{-1} showed higher weed control efficiency and lesser weed density, nutrient uptake at reproductive stage of the crop in lowland rice field.

Hassan and Upasani (2015) conducted an experiment which treatment comprised of 4 methods of crop establishment i.e., transplant, SRI, drum seeded and broadcast in main plot and 4 methods of weed control – pyrazosulfuron 0.02 kg ha^{-1} PE + mechanical weeding at 25 DAS or DAT, weeding by cono weeder at 25 DAS or DAT, hand weeding at 25 and 40 DAS or DAT and weedy check in sub-plot. The result revealed that application of pyrazosulfuron 0.20 kg ha^{-1} + one mechanical weeding at 25 DAS or DAT in transplanted or broadcasted rice was the most effective in suppressing weed population and weed dry matter accumulation thereby producing higher rice grain yield compared to other weed control methods.

Ramesha *et al.* (2015) evaluated the phytotoxicity and bio-efficacy of pyrazosulfuron ethyl 10% WP (5, 10, 15 and 20 g ha^{-1} as spray) against the weeds in transplanted rice. Sprays of Saathi (Market Sample) @ 15g ha^{-1}, Pretilachlor 50% EC @ 500 ml ha^{-1}, hand weeding at 15 and 40 days after planting (weed free check) and a weedy check (untreated check) were also evaluated. The dominant weeds were *Echinochloa colona, Panicum repens, Cynodon doctylon, Ludwigia parviflora, Leptochloa chinensis and Cyperus sp*. Pyrazosulfuron ethyl 10% WP at 20 g ha^{-1} was the most effective application in controlling the associated weeds and increasing the grain yield of rice without any phytotoxic effect.

Hashem (2014) conducted an experiment to observe the effects of crop density and reduced rates of Pretilachlor on weed control and grain yield in rice. They reported that at higher rice density, rice grain yield increased significantly from 1927 kg ha^{-1} to 3217 kg ha^{-1} as the rate of pretilachlor increased from 0 to 1.5 L ha^{-1}, but there was no further increase in yield above this rate. At medium and low densities, grain yield increased significantly as the rate of pretilachlor

increased from 0 to 2 L ha^{-1}. In plots treated with recommended rate of pretilachlor (2 L ha^{-1}), there were no significant differences for grain yield among the crop densities, whereas; in untreated plots, the grain yield increased by 51% from low to high crop density. For the 0, 25%, 50% and 75% of recommended rates, weed biomass decreased significantly with increasing rice density, while for the 100% of recommended rate, weed biomass was unaffected with increasing crop density. This study illustrated that planting rice at higher density can reduce herbicide rate by 25% without adverse effect on grain yield and can be an important component of integrated weed management strategy in lowland rice systems.

Jacob *et al*. (2014) conducted an experiment on which pre-emergence herbicides, oxyfluorfen, butachlor and pretilachlor were sprayed respectively at 3 and 6 DAS. Pyrazosulfuron-ethyl, an early post-emergence herbicide, was sprayed at 8 DAS. The herbicides cyhalofop-butyl, fenoxaprop-p-ethyl, metamifop, penoxsulam, bispyribac sodium and azimsulfuron are post-emergence in action and were sprayed at 20 DAS. Hand weeded (hand weeding at 20 and 40 DAS) and unweeded controls were included for comparison with the herbicide treatments. The best herbicide for control of grass weeds was either fenoxaprop-p-ethyl @ 60 g ha^{-1} or cyhalofop-butyl @ 80 g ha^{-1}, both applied at 20 DAS.

Mallikarjun *et al.* (2014) studied the effect of herbicides on weed control and yield of wet seeded rice which involves three pre-emergence herbicides viz., butachlor, anilophos fb and oxyflurofen applied as alone and each of these followed by two post-emergent herbicides 2, 4- sodium salt, bispyribac sodium and one hand weeding at 25 days. The results revealed that sequential application of butachlor and anilophos fb, bispyribac sodium, 2, 4-D sodium salt and one hand weeding at 25 days was recorded significantly lower weed population and dry weight of weeds viz., monocots, dicots and sedges in equal manner which ultimately indicates that higher weed control efficiency over rest of the treatments except weed free check and hand weeding thrice.

Acharya and Bhattacharya (2013) investigated the efficacy of sulfonyl urea herbicide like pyrazosulfuron-ethyl, benzothiadiazinone like bentazon alone and its combination with MCPA, clefoxydim and quinclorac were studied in comparison to traditional acetamides like butachlor and pretilachlor under field condition in transplanted Boro rice. The dominating weed species in the experimental site were grasses like *Echinochloa crus-galli*, *Paspalum distichum*, sedges like C*yperus iria*, *Fimbristylis miliacea* and broadleaved weeds like *Ammania baccifera* and *Ludwigia parviflora*. The herbicidal treatments were significantly superior to weedy check. There was 32.97% reduction in the grain yield of rice due to competition with weeds in the weedy plots. Application of pre-emergence herbicide pyrazosulfuron ethyl @ 30 g ha^{-1}, with a weed control efficiency of 71.78%, was recorded to be the most effective in controlling predominant weeds, in comparison to acetamide and benzothiadiazinone herbicides. In terms of profitability, application of pyrazosulfuron ethyl @ 20 g ha^{-1} gave the highest gross and net return than other weed control treatments.

Faruq (2013) from his field research on the effect of herbicide (Prechlor 500 EC) on the growth and yield of transplant Aman rice found that application of Prechlor 500 EC @ 1.5 L ha^{-1} showed the best performance in reducing weed density, weed dry weight and in increasing weed control efficiency but reduced the grain yield.

Al-Mamun *et al.* (2011) carried out an experiment to find out an effective and economic herbicide to control weeds in winter rice field. Surjamoni and BRRI dhan29 were used as rice cultivars. Weed control treatments were assigned using three rates of Becolor 5G (butachlor), Bouncer 10WP (pyrazosulfuron-ethyl) and Becofit 500EC (Pretilachlor). Visual observation indicated that these herbicides were not toxic to rice plants. Weed control efficiency ranged (WCE) from 42 to 84%. Above 80% WCE was obtained by Becolor 5G @ 30 kg ha^{-1}, Bouncer 10WP @ 150 g ha^{-1} and Becofit 500EC @ 1.20 L ha^{-1}, respectively.

Bhuiyan *et al.* (2011 a) found that pre-emergence application of Sofit N 300EC @ 450 and 600 g a.i. ha^{-1} led to more than 80% weed control efficiency, the

lowest weed number and dry weight of weeds which eventually resulted in lower weed index, higher yield attributes and grain yield of rice that were comparable to weed free conditions.

Mamun *et al*. (2011 b) carried out a field experiments to evaluate the efficiency of Bensulfuron-methyl + Pretilachlor 6.6% GR for weed suppression and its impacts on transplanted rice. They found that application of Bensulfuron-methyl + Pretilachlor 6.6% GR @ 652 g a.i. ha^{-1} gave more than 80% weed control efficiency.

Shultana *et al.* (2011) conducted an experiment to evaluate the weed control efficiency of some pre-emergence herbicides in transplanted rice. Among the evaluated herbicides, Rigid 50 EC (pretilachlor) @ 1 L, Alert 18WP (bensulfuron + acetachlor) @ 400 g, Kildor 5G (butachlor) @ 25 kg, Bigboss 500EC (pretilachlor) @ 1 L, Rifit 500EC (pretilachlor) @ 1 L, Ravchlor 5G (butachlor) @ 25 kg, Succour 50EC (pretilachlor) @ 1 L and Topstar 80WP (oxadiazon) @ 75 g ha^{-1} showed above 80% weed control efficiency and the grain yield was above 4.00 t/ha.

Ali *et al.* (2010) carried out an experiment on integrated weed management and spacing to evaluate degree of weed control and yield of transplanted aman rice (cv. BRRI dhan37). They observed that among the weed control treatments, Pretilachlor + one hand weeding at 40 DAT was most effective one for controlling weeds at 30 DAT (79.53%) and moderate for controlling weeds at 60 DAT (75.65%) which ultimately contributed to the highest grain yield (3.60 t ha^{-1}).

Bari (2010) carried out an experiment using eight herbicides, i.e. Oxadiazone, Butachlor, Pretilachlor and Anilphos from pre-emergence category, and MCPA, Ethoxysulfuran, Pyrazosulfuran-Ethyl and Oxadiarzil from post-emergence category in transplanted wetland rice during *aman* (autumn), *aus* (summer) and *boro* (winter) growing seasons to study their effects on weed control and rice yield. He found that pre-emergence herbicides performed better regarding weed control efficiency and rice yield. Based on the initial performance, butachlor and

MCPA were further applied at concentrations ranging from 50% to 150% of the recommended rates in transplanted *aus* rice in 2009. Data indicated that butachlor provided better weed control efficiency and contributed to better crop growth and grain yield compared to MCPA irrespective of concentration. It might be due to that pre-emergence application of Butachlor provided effective early season weed control, which MCPA could not since it was applied as post-emergence.

Bhuiyan *et al.* (2010) conducted an experiment during boro season for observing the control of mixed weed flora in transplanted rice (*Oryza sativa L.*). They reported that pre-emergence application of Oxadiargyl 400SC @ 75 g a.i. ha^{-1} had minimum population and dry weight of weeds which resulted satisfactory weed control efficiency than other herbicides and doses. They also reported that Oxadiargyl 400SC caused light phytotoxicity to rice plants when applied @ 100 g a.i. ha^{-1}.

Bakare *et al.* (2008) observed that a formulated mixture of propanil + triclopyr at 2, 3 and 4 L ha^{-1} alongside with a check chemical (OrizoplusR made up of propanil + 2, 4-D Amine) showed significant difference in the level of weed control. Though Propanil + triclopyr controlled weeds; the control level was significantly lower than the check OrizoplusR in each respective application rate. There was no phytotoxic effect of the herbicides on rice, indicating that the herbicides are not injurious to rice crop. Propanil + triclopyr at 3–4 L $ha^{-1}$is a post-emergence herbicide applied in lowland rice.

Kabir *et al.* (2008) stated that weed control efficiency were significantly influenced by different weed control treatments under various water management practices in transplanted *aman* rice field. Other than weed free treatment, Butachlor 5 G @ 2 kg ha^{-1} applied at 7 DAT along with one hand weeding at 40 DAT showed the best performance under good water management with minimum weed density (16 g m^{-2}) as well as weed biomass (9.27 g m^{-2}) and the highest weed control efficiency (82.57%).

Shamim *et al.* (2008) reported the methods of crop establishment, time of herbicide application and their interaction significantly influenced the number and dry weight of weeds and yield of boro rice cv. BRRI dhan29. The highest number and dry weight of weed were recorded in direct seeded thin row, followed by direct seeded thick row and the lowest in transplanting. Again, the highest number and dry weight of weed were recorded in control and the lowest in herbicide application after 3 days of seeding or transplanting. Weed control efficiency was higher in those receiving early application of herbicide. The highest weed control efficiency was in herbicide application at 3 days after seeding or transplanting. Phytotoxicity of herbicide increased with the earliness of herbicide application and highest phytotoxicity was observed in direct seeded thick row having herbicide application 3 days after sowing.

Mukherjee and Malty (2007) reported that Butachlor 1.0 kg ha^{-1} at 3 days after transplanting + almix 20 WP (Chlorimuron-7 ethyl + Metsulfuron-methyl) 4.0 g ha^{-1} at 20 days after transplanting showed higher weed control efficiency and grain yield compared with season long weed control and weed-free condition on transplanted rice.

Samar *et al.* (2007) conducted an experiment to evaluate the effects of herbicides for managing weeds and optimizing the yield of wet seeded rice. It was concluded that application of Pendimethalin (1000 g a.i. ha^{-1}) or Pretilachlor with Safener (500 g a.i. ha^{-1}) as pre-emergence applications followed by one hand-weeding were effective in controlling weeds, increasing grain yield of rice, and resulting in higher net returns than the weed-free treatment.

Singh *et al.* (2004 a) observed that the pre-emergence application of anilofos followed by 2,4-D as post emergence proved superior in controlling weeds compared to cyhalofop-butyl and nutasulfuronmethyl + chlorimuron-ethyl, and was at par with manual weeding at 25 and 50 DAS in Boro rice field.

Kalhirvelan and Vaiyapuri (2003) observed the effect of weed management practices on transplanted rice using Pretilachlor at 187, 250 and 375 g ha^{-1}, Pretilachlor and 2, 4-D at 180 + 180, 240 + 240 and 300 + 300 g ha^{-1} with twice

hand weeding. They found that hand weeding treatment recorded the lowest weed population (2.78 m^{-2}) and weed dry weight (155.70 kg ha^{-1}). Pretilachlor and 2, 4-D at 300 + 300 g ha^{-1} caused the lowest weed density and weed dry weight. Hand weeding recorded the highest grain and straw yields (5.81 and 7.26 t ha^{-1}, respectively) than Pretilachlor and 2, 4-D (5.55 and 6.89 t ha^{-1}).

Mahajan *et al.* (2003) showed that application of Pretilachlor alone or in combination with Safener and hand weeding resulted in the lowest weed density and weed dry matter with the highest grain yield and number of panicles.

Saini (2003) conducted a field investigation to evaluate the efficacy of Pyrazosulfuron-ethyl, in transplanted rice (cv. RP-2421). Pyrazosulfuron-ethyl at 20 g ha^{-1} applied as spray was as effective as its higher rate (25 g ha^{-1}) applied as spray and broadcast after sand mix in terms of the reduction of the dry weight of grasses, sedges, broadleaf and total weeds, and enhanced the grain yield and almost all the yield attributes of rice.

Jena *et al.* (2002) observed that weed control treatments reduced weed density, dry matter and increased rice yield and Oxadiazon gave better weed control. They also found that application of Oxadiazon with hand weeding gave the highest weed control efficiency, grain and straw yield and harvest index.

Rangaraju (2002) carried out a field trial to determine the effect of herbicidal application and time of application on weed flora and weed dynamics of dry seeded rainfed rice. He observed that application of either Butachlor or Thiobencarb at 1.5 kg a.i. ha^{-1} effectively controlled the weeds.

Gnanasambandan and Murthy (2001) Butachlor @ 1250 g ha^{-1} is a pre-emergence herbicide, which was applied at 4 days after transplanting and reported that the treatment effectively controlled weed density and increased grain yield.

Islam *et al.* (2001) investigated the application of few doses of Pretilachlor (312.50−562.50 g a.i. ha^{-1}) and one hand weeding in transplanted rice. They

found that Pretilachlor (312.50−562.50 a.i. ha^{-1}) and one hand weeding reduced weed population and dry matter weight.

Rajkhowa *et al.* (2001) carried out a field trial to find out the most effective weed control and nutrient management practices for rice. Results revealed that Butachlor @ 1.0 kg ha^{-1} or Pretilachlor @ 0.75 kg ha^{-1} applied three days after transplanting significantly reduced weed infestation until 45 DAT and resulted in higher yield of rice over weedy check.

Agazzani *et al.* (1999) set up a field research to determine the best chemical control program against weeds in irrigated fields of dry sown rice. They found that effective weed control was obtained with pre-emergence applications of Pendimethalin alone or mixed with Thiobencarb and Oxadiazon followed by post-emergence herbicidal treatments.

Ahmed *et al.* (1999) compared Oxadiazon and Cinosulfuron with hand weeding control of weeds in wet seeded rice field and observed that Oxadiazon and Cinsolfuron controlled weeds in rice effectively providing 91−92% and 90−92% weed control efficiency, respectively.

Balaswamy (1999) found that hand weeding twice at 20 and 40 days after transplanting resulted in low weed numbers in transplanted rice followed by herbicides.

Sharma and Bhunia (1999) reported that Pendimethalin @ 1.5 kg ha^{-1} + one hand weeding resulted in the highest weed control efficiency in transplanted rice field than any other treatments.

Chandra *et al.* (1998) observed that Oxadiazon 0.8 kg ha^{-1}, Butachlor 2.00 kg ha^{-1} and Thiobencarb 2.00 kg ha^{-1} provided 80.50, 78.30 and 35.10% weed control respectively in direct seeded puddled rice field. They found that Oxadiazon and Thiobencarb increased grain yield. Among the herbicides, Oxadiazon was the most effective herbicidal treatment.

Mumal *et al.* (1998) observed that the weed species *Cyperus sp., Eichhornia crassipes, Echinochloa crus-galli, Echinochloa colonum, Fimbristylis sp., Monochoria vaginalis, Eclipta alba, Paspalum sp., Panicum sp., Commelina sp.* and *Cyanotis* sp. were significantly reduced by the application of Butachlor (at 1 kg active ingredient ha^{-1}), with monocot weeds being controlled better in sprouted direct seeded paddy field under rainfed conditions. Yield was influenced by the time of herbicide application. Maximum weed control was observed when Butachlor was applied 1, 3, 5 and 7 days after broadcasting sprouted seeds.

Ahmed *et al.* (1997) reported that higher weed control efficiency (90.35%) was observed in herbicidal application with one hand weeding treatment than sole herbicides or conventional weed control methods to control weeds in aus rice field.

Brar *et al.* (1997) assessed the efficacy of 0.5 kg Oxadiazon applied 5−15 days after transplanting compared to 0.3 kg Anilofos applied 3 days after transplanting (DAT) and hand weeding twice, for control of *Echinochloa crus-galli* in rice cv. PR−110 in sandy loam soil. Results indicated that the best weed control and crop yield were achieved with Oxadiazon treatment applied at less than 10 DAT, these results were comparable to those achieved with Anilofos or hand weeding.

BRRI (1997) observed that herbicide Set-off and Ronstar perform better than Golteer herbicide with weed biomass, plant population and other plant characters of rice. However, two hand weedings showed the best performance in all respects. On the other hand, two hand weedings gave the highest weeding cost.

Alam *et al.* (1996) stated that weed control efficiency was higher in two hand weeding (90.67%) than dose of Oxadiazon and Cinosulfuron treatments in transplanted aus rice.

Samanta *et al.* (1995) evaluated the performance of weed control by manual weeding and with Oxadiazon in transplanted aman rice (BR11). Oxadiazon (Ronstar 25 EC @ 2.0−4.0 L ha^{-1}) and manual weeding twice were found

effective in reducing the dry matter of total weeds significantly over the control treatment, but none of the treatments except manual weeding twice controlled *Paspalum distichum* effectively in rice field.

Chon *et al.* (1994) reported that pre-emergence application of Butachlor @ 3.6 kg ha^{-1} inhibited shoot growth and development of *Echinochloa cruss-galli* and the rice plants showed a reduction and constriction of thickness of the leaf primordium while *Echinochloa cruss-galli* formed tubular like leaves and inhibited the elongation of the apical meristem.

Savithri *et al.* (1994) described the efficiency of different pre-emergence herbicides in transplanted rice and they concluded that among the different herbicides, application of granular formulation of Butachlor @ 1.5 kg a.i. ha^{-1} at six days after transplantation was found to be the most effective for controlling weeds in transplanted rice.

Singh and Singh (1994) found that all weed control treatments decreased total number of weeds and weed dry weight in transplanted rice in rainfed low land condition. Among them the highest grain yields were observed by the application of Oxadiazon 0.4 kg a.i. ha^{-1}.

Janardhan *et al.* (1993) evaluated pre-emergence Pretilachlor 0.5−1.0 kg ha^{-1} on weed control in transplanted rice. They found that herbicidal treatment decreased weed dry weight and increased grain yield.

Kurmi and Das (1993) carried out an experiment on clay loam soil to evaluate the effect of pretilachlor (0.75–1.25 kg ha^{-1}) applied at 3 DAT, Pyrazosulfuron-ethyl (0.005–0.01 kg ha^{-1}) at 3 and 7 DAT, anilofos (0.4–0.6 kg ha^{-1}) at 7 DAT, Oxidiazon (0.4 kg ha^{-1}) at 7 DAT, 2,4-D (0.8 kg ha^{-1}) at 7 DAT and hand weeding twice at 20 and 40 DAT for controlling weeds in rice cv. IET 6987. All weed control treatments reduced weed dry matter from unweeded control values of 164.2–249.3 g m^{-2} to 20.3–131.0 g m^{-2} and increased rice grain yields from 2016–2768 kg ha^{-1} to 4321–4757 kg ha^{-1}. Pyrazosulfuron-ethyl at 0.01 kg ha^{-1} applied at 7 DAT resulted in the greatest weed control (74.4–77.5%).

Singh and Bhan (1992) observed that two hand weeding resulted better weed control efficiency (72.3%) than Butachlor @ 1.5 kg ha^{-1} (54.4%) in transplanted rice under medium land condition.

Biswas *et al.* (1991) evaluated that Oxadiazon 1.0 and 0.5 kg a.i. ha^{-1} applied at 30 days after sowing with or without one supplemental hand weeding was compared with normal hand weeding and the results indicated that the use of Oxadiazon at 0.5 kg a.i. ha^{-1} was more economic than hand weeding for effective weed management in direct seeded rice field.

Burhan *et al.* (1989) observed that Cinosulfuron @ 20 g ha^{-1} resulted in 85% control of *Monochoria vaginalis, Marsilea crenata, Cyperus spp, Fimbristylis miliacea* and *Scirpus juncoides* but only 50−60 % control of *Echinochloa crus-galli* in transplanted rice.

Mian and mamun (1989) observed that the weed species *Cyperus spp., Eichhornia crassipes, Echinochloa crus-galli, Echinochloa colonum, Fimbristylis sp., Monochoria vaginalis, Eclipta alba, Paspalum sp., Panicum sp., Commelina sp.* and *Cyanotis sp.* were significantly reduced by the application of Butachlor (at 1 kg active ingredient ha^{-1}) in transplanted Aman rice field. Yield was influenced by the time of herbicide application. Maximum weed control was observed when Butachlor was applied at 1, 3, 5 and 7 days after broadcasting the sprouted seeds.

Zafar (1989) assessed an experiment to compare the relative performance of Butachlor (Machete 60 EC at 1.2 kg ha^{-1}), Oxadiazon (Ronstar at 0.54 kg ha^{-1}), Thiobencarb (Stam F 10 G at 1.43 kg ha^{-1}) and Endimethalin (Stam 33 EC at 1.43 kg ha^{-1}) in irrigated transplanted rice field. All herbicides gave above 83% weed control. Tillering in rice plants was not significantly enhanced by Oxadiazon application but increased rice yield.

BRRI (1987) evaluated the performance of herbicides Set-off, Ronstar and Golteer for controlling weeds and optimum grain yield of wet seeded aus rice. The treatments were (a) Sett-off 20 WG 100g ha^{-1} (b) Ronstar 25EC 2.0 L ha^{-1}

(c) Golteer 5G 25 kg ha^{-1} (d) two hand weeding at 20 and 35 DAT and (e) no weeding (control). The most effective way of weed control was Set-off and Ronstar than Golteer in terms of reducing weed biomass and plant population.

After studying the above information and literature the performance of different weed control methods varies under different agro-ecological conditions. It can be concluded that variety and weed control methods have significant effect on the growth and yield of aromatic aman rice.

CHAPTER III

MATERIALS AND METHODS

This chapter presents a brief description about experimental period, site description, climatic condition, crop or planting materials, treatments, experimental design, crop growing procedure, fertilizer application, uprooting of seedlings, intercultural operations, data collection and statistical analysis.

3.1 Location of the experimental field

The field experiment was conducted at the Agronomy field laboratory, Sher-e-Bangla Agricultural University, Dhaka during the period from July to December 2018. The location of the experimental site has been shown in Appendix I.

3.2 Soil of the experimental field

Soil of the experimental site was silty clay loam in texture belonging to Tejgaon series. The area represents the Agro-Ecological Zone of Madhupur tract (AEZ No. 28) with pH 5.6. The analytical data of the soil sample collected from the experimental area were determined in the Soil Resources Development Institute (SRDI), Soil Testing Laboratory, Khamarbari, Dhaka and have been presented in Appendix II.

3.3 Climate of the experimental field

The experimental area was under the subtropical climate and was characterized by high temperature, high humidity and heavy precipitation with occasional gusty winds during the period from April to September, but scanty rainfall associated with moderately low temperature prevailed during the period from October to March. The detailed meteorological data in respect of air temperature, relative humidity, rainfall and sunshine hour recorded by the meteorology center, Dhaka for the period of experimentation have been presented in Appendix III.

3.4 Plant materials and features

Rice cv. BRRI dhan38, BRRI dhan70 and BRRI dhan80 were used as plant materials for the present study. These varieties are recommended for aman season. The features of these three varieties are presented below:

BRRI dhan38: BRRI dhan38 an aromatic rice variety and is grown in *aman* season. It is a modern transplanted *aman* rice released by BRRI in 1997. The grain is short, thick and scented. The cultivar matures at 140 days of planting. It attains a plant height 117 cm. It is semi-photosensitive and semi-lodging tolerant. Its grain is long slender. The cultivar gives an average yield of 3.50 t ha^{-1} (BRRI, 2011).

BRRI dhan70: BRRI dhan70 an aromatic rice variety and is grown in *aman* season. It is modern transplanted *aman* rice released by BRRI in 2014. The grain is short, thick and scented. The cultivar matures at 130 days of planting. It attains a plant height 125 cm, 1000 seed weight 20 g and amailos 21.70%. It is semi-photosensitive and semi-lodging tolerant. Its grain is long slender. The cultivar gives an average yield of 4.80 t ha^{-1} (BRRI, 2016).

BRRI dhan80: BRRI dhan80 an aromatic rice variety and is grown in *aman* season. It is modern transplanted *aman* rice released by BRRI in 2017. The grain is short, thick and scented. The cultivar matures at 130–135 days of planting. It attains a plant height 120 cm, 1000 seed weight 26.2 g and amaylos 23.60%. It is semi-photosensitive and semi-lodging tolerant. Its grain is long slender. The cultivar gives an average yield of 4.50–5.00 t ha^{-1} (BRRI, 2018).

3.5 Description of the herbicides in tabular form

A short description of the herbicides used in the experiment is given in the table below:

Trade Name	Common Name	Mode of Action	Selectivity	Time of Application
Londax Changer	Bensulfuron methyl 10% WP @50 g ha^{-1}	Systemic	For rice	Pre-emergence
Super powder	Pyrazosulfuron ethyl 70% WG @ 15 g ha^{-1}	Systemic	For rice	Pre-emergence
Cimarron	Metsulfuron methyl 20% WP @ 20 g ha^{-1}	Systemic	For rice	Pre-emergence

3.6 Experimental treatments

The experiment consisted of two factors as mentioned below:

Factor A: Herbicide-4

H_0 – Control (No herbicide used, no weeding),

H_1 – Pyrazosulfuron ethyl 70% WG @ 15 g ha^{-1}

H_2 – Bensulfuron methyl 10% WP @ 50 g ha^{-1} and

H_3 – Metsulfuron methyl 20% WP @ 20 g ha^{-1}.

Factor B: Variety-3

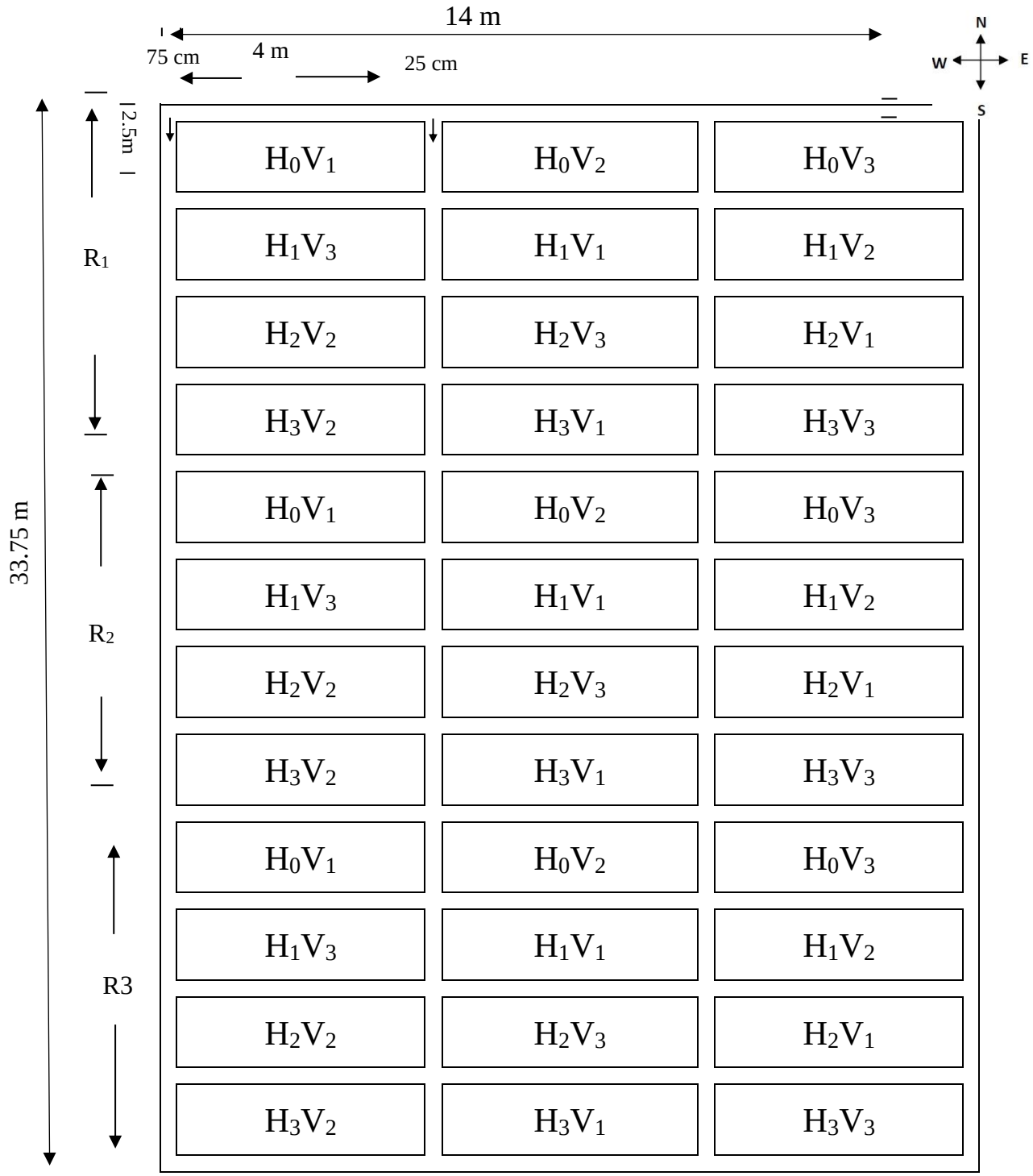
V_1 – BRRI dhan38,

V_2 – BRRI dhan70 and

V_3 – BRRI dhan80.

3.7 Design and layout

The experiment was laid out in a split plot design with three replications. The size of the individual plot was 4 m × 2.5 m and total numbers of plots were 36. There were 12 treatment combinations. Each block was divided into 4-unit plots. Herbicidal weed control was placed along the main plot and rice variety in the sub plot. Lay out of the experiment was done on 26 July, 2018 with inter plot spacing of 0.25 m and inter block spacing of 0.50 m.



Unit Plot Size = 4.0 m × 2.5 m
Plot Spacing = 0.25 m
Between replication = 0.50 m

Figure 1: Field layout of the experiment in split plot design

3.8 Cultivation procedure

3.8.1 Growing of Crop

3.8.1.1 Plant materials collection

Healthy and vigorous seeds of aromatic aman rice cv. BRRI dhan38, BRRI dhan70 and BRRI dhan80 were collected from Bangladesh Rice Research Institute, Joydebpur, Gazipur.

3.8.1.2 Seed sprouting

Healthy seeds were selected by specific gravity method. Seeds were then immersed in water in bucket for 24 hours. Then seeds were taken out of water and kept thickly in gunny bags. The seeds started sprouting after 48 hours and were sown after 72 hours.

3.8.1.3 Seed bed preparation and seedling raising

A piece of high land was selected in the Agronomy Field Laboratory, Sher-e-Bangla Agricultural University, Dhaka for raising seedlings. The land was puddled well with country plough followed by leveling with a ladder. The sprouted seeds were sown in the seedbed on 30 June, 2018. Proper care was taken to raise the healthy seedlings in the nursery bed. Weeds were removed and irrigation was given in the nursery bed as and when necessary.

3.8.1.4 Final land preparation

The land was first opened with a tractor drawn disc plough on 20 July, 2018. The land was then puddled thoroughly by repeated ploughing and cross ploughing with a country plough and subsequently levelled by laddering. The field layout was made on 26 July, 2018 according to experimental specification immediately after final land preparation. Weeds and stubbles were cleared off from individual plots and finally plots were levelled properly by wooden plank so that no water pocket could remain in the field.

3.8.1.5 Fertilizer application

The land was fertilized with urea, triple super phosphate, muriate of potash, gypsum and zinc sulphate at 250 kg ha^{-1}, 120 kg ha^{-1}, 120 kg ha^{-1}, 100 kg ha^{-1} and 10 kg ha^{-1}, respectively. The whole amount of triple super phosphate, muriate of potash, gypsum and zinc sulphate were applied at the time of final land preparation. Urea was applied in three equal splits at 10, 30 and 45 DAT.

3.8.1.6 Uprooting of seedlings

The seedbed was made wet by application of water in the morning and evening on the previous day before uprooting. The seedlings were uprooted without causing any mechanical injury to the roots and were kept in the soft mud in shade. The age of seedling on the day of uprooting was thirty days.

3.8.1.7 Transplanting

Thirty days old rice seedlings were transplanted on 29 July, 2018 in 36 experimental plots which were puddled further with spade on the day of transplanting. Transplanting was done by using two seedlings $hill^{-1}$ with 25 cm × 15 cm spacing between the rows and hills, respectively.

3.8.2 Intercultural operation

3.8.2.1 Gap filling

Seedlings in some hills were died off and those were replaced by healthy seedling within 10 days of transplantation.

3.8.2.2 Weeding

No weeding was done in the experimental plot. But after 45 DAT central $1m^2$ area weed was collected for counting the number of weed species.

3.8.2.3 Irrigation and drainage

Flood irrigation was given to maintain a level of standing water up to 2–4 cm untill maximum tillering stage and after that, a water level of 7–10 cm was maintained up to grain filling stage and then drained out after milk stage to enhance maturity.

3.8.2.4 Herbicide application

Herbicides spraying were done by a hand crop sprayer (model: AM S021, capacity: 20 liter, Brand name: AGROS, made in Zhejiang, China, Working Pressure: 0.2-0.3 Mpa) at 5 days after transplanting. When field was containing 3-4 cm standing water for 3-5 days.

3.8.2.5 Plant protection measures

The crop was attacked by yellow rice stem borer (*Scirpopagain certulas*) at the panicle initiation stage which was successfully controlled with Sumithion @ 1.5 L ha^{-1}. Yet to keep the crop growth normal, Basudin was applied at tillering stage @ 17 kg ha^{-1} while Diazinon 60 EC @ 850 ml ha^{-1} were applied to control rice bug.

3.8.2.6 Detecting the flowering stage (50%) and observation of heading

With experience, it was felt that identifying the flowering stage should need to follow with regular field observations as flowering date (50%) were recorded after visual observations.

Variety	Flowering date (50%)
BRRI dhan38	15−10-2018 (75 DAT)
BRRI dhan70	13−10-2018 (70 DAT)
BRRI dhan80	10−10-2018 (65 DAT)

3.8.2.7 General observations of the experimental field

Regular observations were made to see the growth stages of the crop. In general, the field looked nice with normal green plants, which were vigorous and luxuriant in the treatment plots than that of control plots.

3.8.2.8 Harvest and post-harvest operation

The maturity of crop was determined when 85% to 90% of the grains become golden yellow in color. From the centre of each plot, 1 m^2 area was harvested to determine yield of individual treatment and converted into t ha^{-1}. The harvested crop of each plot was bundled separately, tagged properly and brought to threshing floor. The bundles were dried in open sunshine, threshed and then grains were cleaned. The grain and straw weights for each plot were recorded after proper drying in sun. Before harvesting, ten hills $plot^{-1}$ were selected randomly outside the sample area of each plot and cut at the ground level for collecting data on yield contributing characters. The harvesting dates were-

Variety	Harvesting date
BRRI dhan38	15−12-2018 (136 DAT)
BRRI dhan70	07−12-2018 (130 DAT)
BRRI dhan80	02−12-2018 (126 DAT)

3.9 Collection of data

The following data were collected-

3.9.1 Weed parameters data-

a) Weed density
b) Dry matter content of weed (%)
c) Weed control efficiency (%)

3.9.2 Crop parameters data-

3.9.2.1 Growth parameters

a) Plant height (cm)
b) No. of effective tiller hill^{-1}
c) No. of non-effective tiller hill^{-1}
d) Total no. of tiller hill^{-1}

3.9.2.2 Yield contributing parameters

a) Panicle length (cm)
b) No. of filled grains panicle^{-1}
c) No. of unfilled grains panicle^{-1}
d) Total grains panicle^{-1}
e) Weight of 1000 grain(g)
f) Sterility (%)

3.9.2.3 Yield parameters

a) Grain yield (t ha^{-1})
b) Straw yield (t ha^{-1})
c) Biological yield (t ha^{-1})
d) Harvest index (%)

3.10. Procedure of collecting data

3.10.1 Weed parameters

3.10.1.1 Weed density

Data on weed population were collected from each plot at 45 days time of the rice plants. Weeds grown in the quadrate (1 m × 1 m) were identified and the quadrate was placed randomly at three places in each plot as following by Cruz *et al*. (1986) method. The weeds within the quadrate were counted species-wise. The species were identified with the help of 'Bangladesher Agacha Parichiti'

(Karim and Kabir, 1995) and Major Weeds of the Philippines (Moody *et al*., 1984). Observations on weed density were recorded using quadrate method as described by Pound and Clements (1998). Frequency of different weeds were determined and density of each species was calculated according to Odum (1971).

$$\text{Weed density (Number m}^{-2}) = \frac{\text{Total number of weeds}}{\text{Total survayed unit area}}$$

3.10.1.2 Dry matter content of weed (%)

After collection all the weeds from the field, fresh weight of weed was measured by 4-digit electrical balance. Then collected weeds were dried in an electrical oven for 72 hours maintaining a constant temperature of 80°C. After drying, weight of dried weeds was measured by electrical balance. The dry matter content of weed was calculated by the following formula:

$$\text{Dry matter content of weed (\%)} = \frac{\text{Weight of oven dried weed}}{\text{Fresh weight of weed}} \times 100$$

3.10.1.3 Weed control efficacy (%)

Weed control efficiency of different weed control treatments was calculated using the following formula developed by Sawant and Jadhav (1985):

$$\text{Weed control efficiency (\%)} = \frac{\text{DWC - DWT}}{\text{DWC}} \times 100$$

Where,

DWC = Dry weight of weeds in the weedy check

DWT = Dry weight of weeds in the weed management treatment

The extent of weed control by different weed control treatments and susceptibility of different weed species were graded based on weed control efficiency by the following, scales as suggested by Mian and Gaffer (1968).

Degrees of weed susceptibility	Weed control efficacy	Grades of weed control
Complete susceptible (CS)	100	Completely control (CC)
Very highly susceptible (VHS)	90–99	Excellent control (EC)
Highly susceptible (HS)	70–89	Good control (GC)
Moderately susceptible (MS)	40–69	Fair control (FC)
Poorly Susceptible (PS)	20–39	Poor control (PC)
Slightly susceptible (SS)	1–19	Slightly control (SC)
Completely resistant (CR)	0	No control (NC)

3.10.2 Crop parameters

3.10.2.1 Plant height (cm)

The height of plant was recorded in centimeter (cm) at the time of harvest from the 10 randomly selected plants. The height was measured from ground level up to tip of the uppermost panicle. The average value of the 10 hills was recorded as plant height.

3.10.2.2 Number of effective tillers hill^{-1}

Data on effective tiller per hill were recorded from 10 randomly selected hill at harvesting time and average value was recorded. Panicles having at least one grain was regarded as effective tiller.

3.10.2.3 Number of non-effective tillers hill^{-1}

Data on non-effective tiller per hill were counted from 10 pre selected (used in effective tiller count) hill at harvesting time and average value was recorded. The tillers which have no panicle was regarded as non effective tiller.

3.10.2.4 Total number of tillers hill^{-1}

Tillers, which had at least one visible leaf, were counted. It included both effective and non-effective tillers.

3.10.2.5 Panicle length (cm)

Panicle length was measured with a meter scale from randomly selected 10 panicles and average value was recorded.

3.10.2.6 Number of filled grains panicle^{-1}

The total number of filled grains was collected from randomly selected 10 plants of a plot and then average number of filled grains per panicle was recorded.

3.10.2.7 Number of unfilled grains penicle^{-1}

The total number of unfilled grains was collected from randomly selected 10 plants of a plot based on no grain in spikelet and then average number of unfilled grains per panicle was recorded.

3.10.2.8 Number of total grains panicle^{-1}

Number of total grains panicle^{-1} was calculated by summation of filled and unfilled grains panicle^{-1}.

3.10.2.9 1000-grains weight (g)

One thousand clean and dried seeds were randomly taken from the 1 m^2 harvesting area of each plot and the weight was taken in an electrical balance.

3.10.2.10 Sterility (%)

The sterility percentage was measured by the following formula:

$$\text{Sterility (\%)} = \frac{\text{Unfilled grain panicle}^{-1}}{\text{Unfilled grain panicle}^{-1} + \text{Filled grain panicle}^{-1}} \times 100$$

3.10.2.11 Grain yield (t ha^{-1})

Grain yield was calculated from the grains harvested from central 1 m^2 area. The crop of each plot was bundle separately, tagged properly and brought to the threshing floor. The grain weights for each plot were recorded after poper sun drying. Final grain yield was adjusted at 14% moisture. Total yield should be measured at t ha^{-1}.

3.10.2.12 Straw yield (t ha^{-1})

Straw weight was taken from central 1m^2 harvested area. Each plot of data was recorded seperately. Total yield should be measured at t ha^{-1}**.**

3.10.2.13 Biological yield (t ha^{-1})

Grain yield together with straw yield was regarded as biological yield and calculated with the following formula:

$$\text{Biological yield (t ha}^{-1}\text{)} = \text{Grain yield (t ha}^{-1}\text{)} + \text{Straw yield (t ha}^{-1}\text{)}$$

3.10.2.14 Harvest Index (%)

Harvest index denotes the ratio of economic yield to biological yield and was calculated with the following formula:

$$\text{Harvest Index (\%)} = \frac{\text{Economic Yield}}{\text{Biological Yield}} \times 100$$

(Economic yield=Grain weight; Biological yield=Grain weight+Straw weight)

3.11 Statistical Analysis

The recorded data were compiled and subjected to statistical analysis. Analysis of variance was done Statistix 10 computerized package program. The significant differences among the treatment means were compared by Least Significant Difference (LSD) at 5% levels of probability (Gomez and Gomez, 1984).

CHAPTER IV

RESULTS AND DISCUSSION

This chapter comprises presentation and discussion of the results obtained from a study to investigate performance of different herbicides to control weed in aromatic rice. The results of the weed parameters and crop characters of the production of the crop as influenced by different weed control treatments have been presented and discussed in this chapter. Diversity of infested weed species in the experimental plot and their details are shown in Table 1. The results related to weed infestation and weed control have been presented in Tables 2–4. Data on different crop characters have been presented in Table 5–12 and Figure 1–12. The analyses of variance (ANOVA) on different parameters were calculated and presented in Appendices IV to VII.

4.1 Weed parameters

4.1.1 Diversity of infested weed species

It is a general observation that the favorable conditions for growing aromatic *aman* rice are also favorable for exuberant growth of numerous kinds of weeds that compete with crop plants. Weed competition is strong when the weed population increases and the weed growth is comparatively more exuberant and rapid than those of the desired crop plants. The plots without herbicide and no hand weeding were infested with different weed species. The twenty-five weed species infested the total experimental field, which belongs to twelve families (Table 1). Among these species 7 belonged to Cyperaceae, 6 Poaceae, 3 Asteraceae, 2 Amaranthaceae, 2 Onagracceae, 1 from each of Marsileaceae, Commelinaceae, Scrophulinaceae, Alismataceae, Brassicaceae, Scrophulariaceae, Pontederiaceae families (Table 1). Among the total weed vegetation, 48% were annual and 52% were perennial weed species (Table 1). Weeds grown in the experimental plot were grass, aquatic fern, broad-leaved,

sedge type. The particulars of weed's common name, English name, scientific name, family name, life cycle and types have been presented in Table 1.

The most important weeds of the experimental plot were *Cyperus michelianus, Echinochloa cruss-galli, Cyperus esculentus, Sagittaria guyanensis, Alternanthera sessilis, Marsilea crenata, Cyperus difformis, Sphenoclea zeylanica* and *Ludwigia octovalvis*, respectively. Among the twenty-five species, eight were aquatic, seven were grasses, six were sedges, five were broad leaved and one was fern (Table 2). From a survey in BRRI farm, Bhanga, Faridpur and Burichang of Comilla district, Bangladesh, Bhuiyan *et al.* (2011 a) also reported that weed flora in the experimental plots observed in two agro-ecological zones comprised of grasses *Cynadon dactylon, Echinochloa crus-galli, Leptochloa chinensis*, the sedges*; Cyperus difformis, Scirpus juncoides, Fimbristylis miliaceae* and the broadleafs*; Monochoria vaginalis, Lindernia anagallis, Marsilea minuta and Sphenoclea zeylanica.* Mamun *et al.* (2011) reported that *Echinochloa crus-galli, Scirpus maritimus, Monochoria vaginalis, Cyperus difformis, Cynodon dactylon, Marsilea minuta, Ludwigia octovalvis*, *Nymphaea nouchali* and *Desmodium trifolium* were important weed species of transplanted *aman* rice. The present result varied a little bit from those reports and this might be due to seasonal variation and location.

Table 1: Diversity of infested weed species in the experimental plot

Sl. No.	Common Name	English name	Scientific name	Family name	Life cycle	Types
01	Behua	Small flowered umbrella	*Cyperus difformis*	Cyperaceae	Annual	Sedge
02	Bara Shama	Barnyard grass	*Echinochloa crusgalli* L.	Poaceae	Annual	Grass
03	Shusni Shak	Shusni Shak	*Marsilea crenata*	Marsileaceae	Annual	Fern
04	Arail	Southern cutgrass	*Leersia hexandra*	Poaceae	Annual	Grass
05	Keshuti	White eclipta	*Eclipta alba*	Asteraceae	Annual	Broadleaf
06	Kanaibashi	Spider wort	*Commelina diffusa*	Commelinaceae	Annual	Aquatic
07	Matichaise	Alligator weed	*Fimbristylis miliacea*	Cyperaceae	Annual	Aquatic
08	Khetpapri	Khetpapri	*Lindemia procumbens*	Scrophulariaceae	Annual	Broadleaf
09	Chandmala	Duck weed	*Sagittaria guyanensis*	Alismataceae	Annual	Aquatic
10	Nakful	Nutsedge	*Cyperus michelianus*	Cyperaceae	Annual	Sedge
11	Joyna	Fringerush	*Fimbristylis miliaceae*	Cyperaceae	Annual	Sedge
12	Mutha	Nutgrass	*Cyperus rotundus*	Cyperaceae	Annual	Sedge
13	Moyurleja	Mucronate sprangletop	*Leptochloa panicea*	Poaceae	Annual	Grass

Sl. No.	Common Name	English name	Scientific name	Family name	Life cycle	Types
14	Chanchi	Chanchi	*Alternathera sessilis*	Amaranthaceae	Perennial	Aquatic
15	Durba	Bermuda grass	*Cynodon dactylon L.*	Poaceae	Perennial	Grass
16	Jhilmorich	Gooseweed	*Sphenoclea zeylanica*	Sphenocleaceae	Perennial	Broadleaf
17	Panilong	Willow primrose	*Ludwigia octovalvis*	Onagraceae	Perennial	Broadleaf
18	Holdemutha	Yellow nutsedge	*Cyperus esculentus*	Cyperaceae	Perennial	Sedge
19	Chapra	Indian goosegrass	*Eleusine indica*	Poaceae	Perennial	Grass
20	Chotoshama	Jungle rice	*Echinochloa colonum*	Poaceae	Perennial	Grass
21	Ghagra	Cocklebur	*Xanthium indicum*	Asteraceae	Perennial	Aquatic
22	Malancha	Mud sedge	*Alternathera philoxeroides*	Amaranthaceae	Perennial	Aquatic
23	Chech	Mud sedge	*Fimbristylis diphylla*	Cyperaceae	Perennial	Sedge
24	Choto pani kochu	Monochoria	*Monochoria vaginalis*	Pontederiaceae	Perennial	Aquatic
25	Keshordam	Creeping water primrose	*Jussicea repens*	Onagraceae	Perennial	Aquatic

4.1.2 Weed density (Number m^{-2})

4.1.2.1 Effect of herbicidal weed control

Significant variation was observed on weed density at 45 DAT of the growing period for different weed control treatments (Table 2 and Appendix IV). The highest weed population (19.59 m^{-2}) was observed in control (no herbicide used, no weeding, H_0) at 45 DAT. The lowest weed population (5.41 m^{-2}) was observed in case of Metsulfuron methyl 20% WP @ 20 g ha^{-1}(H_3) applied plot. Herbicidal treatments drastically reduced weed population. This result was supported by Bhuiyan *et al.* (2010) who reported that pre-emergence application of Metsulfuron methyl @ 75 g ha^{-1} had minimum population than any other herbicide and doses. Similar results were also stated by Bhuiyan *et al.* (2011 b), Kalhirvelan and Vaiyapuri (2003), Mahajan *et al.* (2003), Gnanasambandan and Murthy (2001), Islam *et al.* (2001), Samanta *et al.* (1995) and Singh and Singh (1994). Rafiquddualla (1999) observed that no weeding regimes produced the highest weed density. Madhukumar *et al*. (2013) reported that unweeded field produces significantly higher total weed density (253 $No.m^{-2}$).

Table 2. Effect of herbicidal weed control on weed density (number m^{-2}), dry matter content of weed (%) and weed control efficiency (%) of aromatic rice field

Herbicide	Weed density (Number m^{-2})	Dry matter content of weed (%)	Weed control efficiency (%)
H_0	19.59 a	21.76 a	-
H_1	12.70 b	15.34 b	28.91
H_2	8.83 c	14.16 b	34.24
H_3	5.41 d	12.79 d	40.29
LSD (0.05)	0.18	0.13	-
CV (%)	7.65	8.91	-

In a column, means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly as per 0.05 level of probability

H_0 – Control, H_1 – Pyrazosulfuron ethyl 70% WG @ 15 g ha^{-1}, H_2 – Bensulfuron methyl 10% WP @ 50 g ha^{-1} and H_3 – Metsulfuron methyl 20% WP @ 20 g ha^{-1}

4.1.2.2 Effect of variety

There observed a significant variation on weed density among the aromatic rice varieties at 45 DAT (Table 3 and Appendix IV). At 45 DAT, highest weed population (13.32 No. m^{-2}) was observed in BRRI dhan80 (V_3). The lowest weed population (9.98 No. m^{-2}) was observed in case of BRRI dhan70 (V_2). These results are in agreement with the findings of Chandra and Pandey (2001) who stated that weed competition was severe in scented paddy culture, in view of its early slow growth rates.

Table 3. Effect of varietal performance on weed density (number m^{-2}), dry matter content of weed (%) and weed control efficiency (%) of aromatic rice field

Aromatic Rice Varieties	Weed density (Number m^{-2})	Dry matter content of weed (%)	Weed control efficiency (%)
V_1	11.59 b	15.10 c	39.70
V_2	9.98 c	15.93 b	44.11
V_3	13.32 a	17.00 a	29.62
LSD (0.05)	0.15	0.15	-
CV (%)	8.65	9.31	-

In a column, means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly as per 0.05 level of probability

V_1 – BRRI dhan38, V_2 – BRRI dhan70 and V_3 – BRRI dhan80

4.1.2.3 Interaction effect of herbicidal weed control and variety

For herbicidal weed control and varietal combination, significant variation was observed for weed density at 45 days of the growing period (Table 4). The maximum weed population (20.01 m^{-2}) was recorded from the combinations of control (no herbicide used, no weeding) and BRRI dhan70 (H_0V_2) and the second maximum population (19.90 m^{-2} and 18.85 m^{-2}) was recorded from H_0V_1 and H_0V_3 respectively. The minimum weed density (3.22 m^{-2}) was observed from the combinations of Metsulfuron methyl 20% WP @ 20 g ha^{-1} and BRRI dhan70

(H_3V_2). This result was similar with the findings of Gnanavel and Anbhazhagan (2010) who observed that Pre-emergence application of Metsulfuron methyl 0.25 kg ha^{-1} followed by post-emergence application of bispyribac sodium 0.05 kg + metsulfuron methyl @ 0.01 kg ha^{-1} recorded the least weed count (11.00 m^{-2}) in transplanted aromatic basmati rice.

Table 4. Interaction effect of herbicidal weed control and varietal performance on weed density (number m^{-2}), dry matter content of weed (%) and weed control efficiency (%) of aromatic rice field

Treatment Combination	Weed density (No. m^{-2})	Dry matter content of weed (%)	Weed control efficiency (%)
H_0V_1	19.90 a	21.55 ab	-
H_0V_2	20.01 a	23.81 a	-
H_0V_3	18.85 ab	19.93 ab	-
H_1V_1	12.10 c	13.33 e	38.14 b
H_1V_2	9.17 d	15.34 cd	35.57 b
H_1V_3	16.84 c	17.34 c	13.00 d
H_2V_1	9.12 d	12.28 e	42.55 b
H_2V_2	7.53 e	14.25 d	40.15 b
H_2V_3	9.80 d	15.94 cd	20.02 c
H_3V_1	5.25 e	13.27 e	38.42 bc
H_3V_2	3.22 f	10.33 f	56.61 a
H_3V_3	7.77 e	14.78 d	25.84 c
LSD (0.05)	0.15	0.15	-
CV (%)	8.65	9.31	-

In a column, means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly as per 0.05 level of probability

H_0 – Control, H_1 – Pyrazosulfuron ethyl 70% WG @ 15 g ha^{-1}, H_2 – Bensulfuron methyl 10% WP @ 50 g ha^{-1} and H_3 – Metsulfuron methyl 20% WP @ 20 g ha^{-1}

V_1 – BRRI dhan38, V_2 – BRRI dhan70 and V_3 – BRRI dhan80

4.1.3 Dry matter content of weed (%)

4.1.3.1 Effect of herbicidal weed control

Significant variation was observed on dry matter content of weed (%) at 45 DAT of the growing period for different weed control treatments (Table 2 and Appendix IV). The maximum dry matter content of weed (21.76%) was observed in control (No herbicide used, no weeding, H_0) and the minimum (12.79%) was observed in case of Metsulfuron methyl 20% WP @ 20 g ha^{-1} (H_3). Rafiqudduallа (1999) observed that no weeding regimes produced the highest weed dry weight. Madhukumar *et al*. (2013) reported that unweeded field produces significantly higher dry matter (42.30 %).

4.1.3.2 Effect of variety

There observed a significant variation on dry matter content of weed (%) among the aromatic rice varieties at 45 DAT (Table 3 and Appendix IV). At 45 DAT, the maximum dry matter content of weed (17.00 %) was observed in BRRI dhan80 (V_3) and then (15.93 %) was observed in BRRI dhan70. The minimum dry matter content of weed (15.10 %) was observed in case of BRRI dhan38 (V_1). The dry matter with BRRI dhan70 may be attributed to the higher crop weed association of weed species.

4.1.3.3 Interaction effect of variety and weed control treatments

For herbicidal weed control and varietal combination, exerted significant variation for dry matter content of weed (%) at 45 days of the growing period shown in Table 4. The maximum dry matter content of weed (23.81 %) was recorded from the combinations of control (no herbicide used, no weeding) and BRRI dhan70 (H_0V_2) and the second maximum dry matter (21.55 %) was recorded from H_0V_1 (no herbicide used and BRRI dhan38). The minimum dry matter content of weed (10.33%) was observed from the combinations of Metsulfuron methyl 20% WP @ 20 g $ha^{-1}$and BRRI dhan70 (H_3V_2).

4.1.4 Weed control efficiency (%)

4.1.4.1 Effect of herbicidal weed control

For different herbicidal weed control treatments, significant variation was observed for weed control efficiency (Table 2 and Appendix VI). At 45 DAT, Metsulfuron methyl 20% WP @ 20 g ha^{-1} (H_3) scored the highest weed control efficiency (40.29%) which was second highest (34.24%) with Bensulfuron methyl 10 % WP @ 50 g ha^{-1} (H_2). The lowest weed control efficiency (0.00%) was observed under control (no herbicide used, no weeding treatment, H_0). This result was similar with Shultana *et al.* (2011) and Bhuiyan *et al.* (2010) who found that Pyrozosulfuron ethyl @ 75 g ha^{-1} showed above 80% weed control efficiency. Also, this result was in agreement with the findings of Al-Mamun *et al.* (2011), Bhuiyan *et al.* (2011), Mamun *et al.* (2011 b), Ali *et al.* (2010), Gnanavel and Anbhazhagan (2010) and Kabir *et al.* (2008).

4.1.4.2 Effect of variety

Significant variation was observed for weed control efficiency due to varietal variation shown in Table 3 and Appendix VI. BRRI dhan70 (V_2) recorded the highest weed control efficiency (44.11%) which was statistically second highest (39.70%) with BRRI dhan38 (V_1). The lowest weed control efficiency (29.62%) was recorded from BRRI dhan80 (V_3). This result was in agreement with Hoque *et al.* (2003) who stated that BRRI dhan38 was the most competitive variety. This result was also supported with Franje *et al.* (1992) who found that tall traditional cultivars to be more competitive than the relatively short stature BRRI advanced lines.

4.1.4.3 Interaction effect of herbicidal weed control and variety

Significant variation was observed for weed control efficiency under different herbicidal weed control and variety treatment combinations (Table 4). The highest weed control efficiency (56.61%) was recorded form combinations of Metsulfuron methyl 20% WP @ 20 g ha^{-1} and BRRI dhan70 (H_3V_2). The lowest

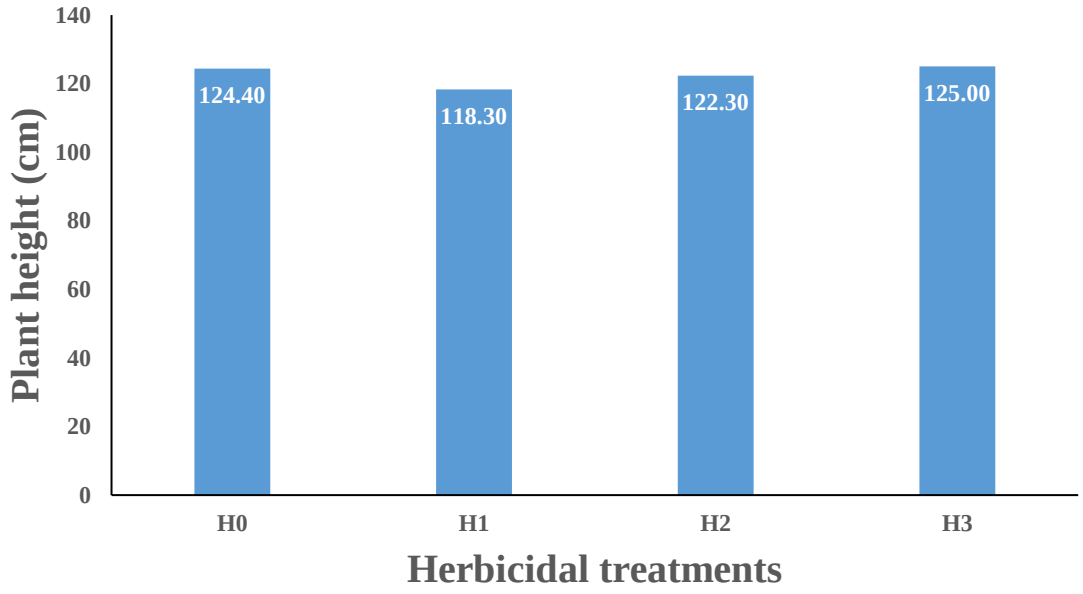
weed control efficiency (0.00%) was observed under control (no herbicide used, no weeding) treatment and all the varieties (BRRI dhan38, BRRI dhan70 and BRRI dhan80) combinations (H_0V_1, H_0V_2 and H_0V_3). This result supported with the findings of Al-Mamun *et al.* (2011) who stated that above 80% WCE was obtained by Becolor 5G @ 30 kg ha^{-1}, Bouncer 10WP @ 150 g ha^{-1} and Becofit 500EC @ 1.20 L ha^{-1}, respectively in Surjamoni and BRRI dhan38. Similar results were reported by Ali *et al.* (2010) who observed that among the weed control treatments Metsulfuron methyl performed best for controlling weeds (79.53%) in transplanted *aman* rice (cv. BRRI dhan38).

4.2 Crop parameters

4.2.1 Plant height (cm)

4.2.1.1 Effect of herbicidal weed control

The plant height varied significantly due to the application of different herbicides in the rice field (Figure 2 and Appendix V). The tallest plant (125.00 cm) was obtained from H_3 (Metsulfuron methyl 20% WP @ 20 g ha^{-1}) treatment which is statistically similar to H_0 (124.40 cm) and H_2 (122.30 cm) treatment. The shortest plant (118.30 cm) was obtained from H_1 (Pyrazosulfuron ethyl 70% WG @ 15 g ha^{-1}) treatment. Attalla and Kholosy (2002) reported that herbicide application significantly enhanced plant height of rice. Weeding reduced crop-weed competition thus enhanced plant height significantly. Similar results were observed by Zannat (2014) and Islam (2014). The results were in agreement with the findings of Khan and Tarique (2011) who found that the highest plant height was observed in completely weed free condition throughout the crop growth period with chemical weed control method and next in two hand weeding treatment whereas lowest value was observed in no weeding treatment. The results were in consistence with the findings of Hasanuzzaman *et al.* (2008), Hasanuzzaman *et al.* (2007) and Haque (1993).

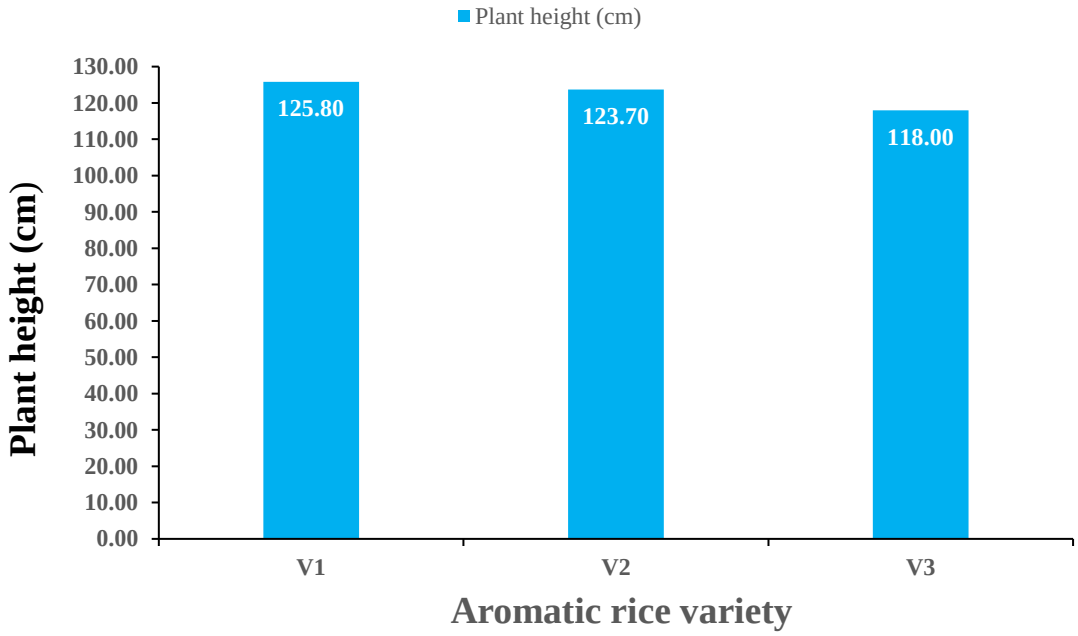


H_0 – Control, H_1 – Pyrazosulfuron ethyl 70% WG @ 15 g ha^{-1}, H_2 – Bensulfuron methyl 10% WP @ 50 g ha^{-1} and H_3 – Metsulfuron methyl 20% WP @ 20 g ha^{-1}

Figure 2: Effect of herbicidal weed control on plant height of aromatic rice variety ($LSD_{0.05}$ = 4.13, at harvesting time)

4.2.1.2 Effect of variety

Plant height varied significantly for varietal variation throughout the going period (Figure 3 and Appendix V). At harvesting time, BRRI dhan38 (V_1) scored the tallest plant (125.80 cm) which was statistically similar (123.70 cm) with BRRI dhan70 (V_2). The shortest plant (118.00 cm) was observed for BRRI dhan80 (V_3). This result was in agreement with Bisne *et al.* (2006) who described that plant height varies significantly among varieties.



V_1 – BRRI dhan38, V_2 – BRRI dhan70 and V_3 – BRRI dhan80

Figure 3: Effect of varietal performance on plant height of aromatic rice variety ($LSD_{0.05}$ = 2.46, at harvesting time)

4.2.1.3 Interaction effect of herbicidal weed control and variety

Plant height was significantly affected by the interaction of herbicidal weed control and variety shown in Table 5. At harvesting time, the tallest plant (128.10 cm) was recorded from the combination of Metsulfuron methyl 20% WP @ 20 g ha^{-1} and BRRI dhan38 (H_3V_1) which was statistically similar with H_0V_1 (127.90cm), H_3V_2 (126.10 cm), H_0V_2 (125.60 cm) and the shortest (114.00 cm) was obtained from Pyrazosulfuron ethyl 70% WG @ 15 g ha^{-1} and BRRI dhan80 (H_1V_3).

Table 5. Interaction effect of herbicidal weed control and varietal performance on plant height (cm) of aromatic rice variety

Treatment combination	Plant height (cm)
H_0V_1	127.90 ab
H_0V_2	125.60 abc
H_0V_3	119.60 ef
H_1V_1	121.60 de
H_1V_2	119.30 ef
H_1V_3	114.00 g
H_2V_1	125.60 bc
H_2V_2	123.70 cd
H_2V_3	117.70 f
H_3V_1	128.10 a
H_3V_2	126.10 abc
H_3V_3	120.80 e
LSD $_{(0.05)}$	2.46
CV (%)	7.16

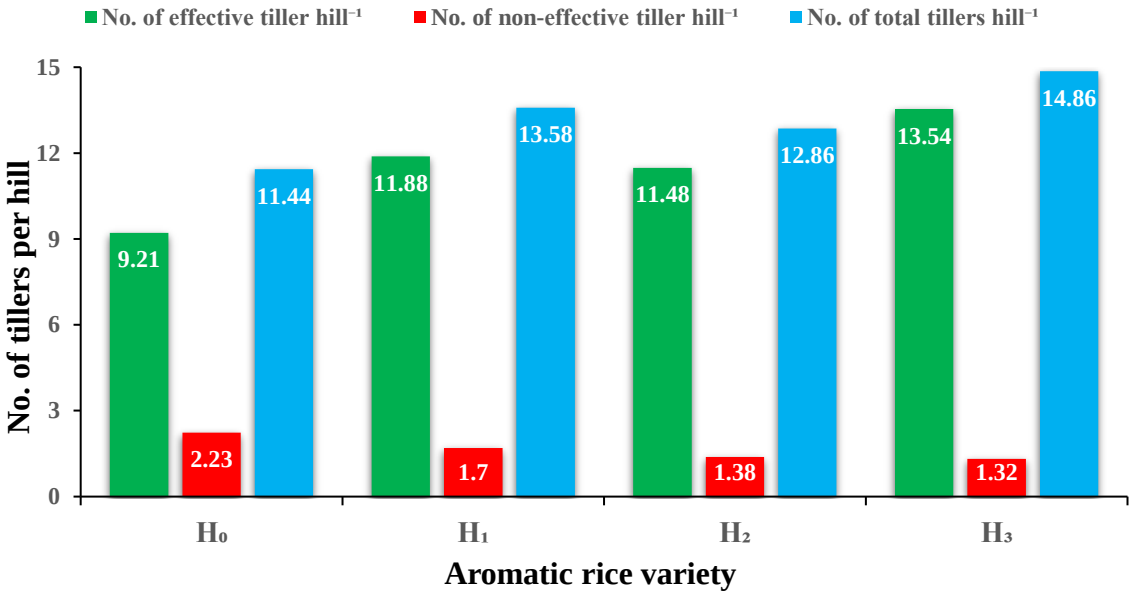
In a column, means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly as per 0.05 level of probability
H_0 – Control, H_1 – Pyrazosulfuron ethyl 70% WG @ 15 g ha^{-1}, H_2 – Bensulfuron methyl 10% WP @ 50 g ha^{-1} and H_3 – Metsulfuron methyl 20% WP @ 20 g ha^{-1}
V_1 – BRRI dhan38, V_2 – BRRI dhan70 and V_3 – BRRI dhan80

4.2.2 Number of effective tillers hill^{-1}

4.2.2.1 Effect of herbicidal weed control

The number of effective tillers hill^{-1} was significantly influenced by different herbicide treatment (Figure 4 and Appendix V). Weed control by Metsulfuron methyl 20% WP @ 20 g ha^{-1} (H_3) gave the highest effective tiller (13.54). The second highest effective tiller (11.88) was obtained from Pyrazosulfuron ethyl 70% WG @ 15 g ha^{-1} (H_1) treatment which was statistically similar with (11.48) Bensulfuron methyl 10% WP @ 50 g ha^{-1} (H_2). The lowest effective tiller (9.20) was obtained from control (H_0, no herbicide used, no weeding) treatment. These

results were similar to the findings of Hasanuzzaman *et al.* (2008) and Raju *et al.* (2003) who stated that use of weedicide (Ronstar 25 EC, Safener and Butachlor) gave the highest effective tiller.



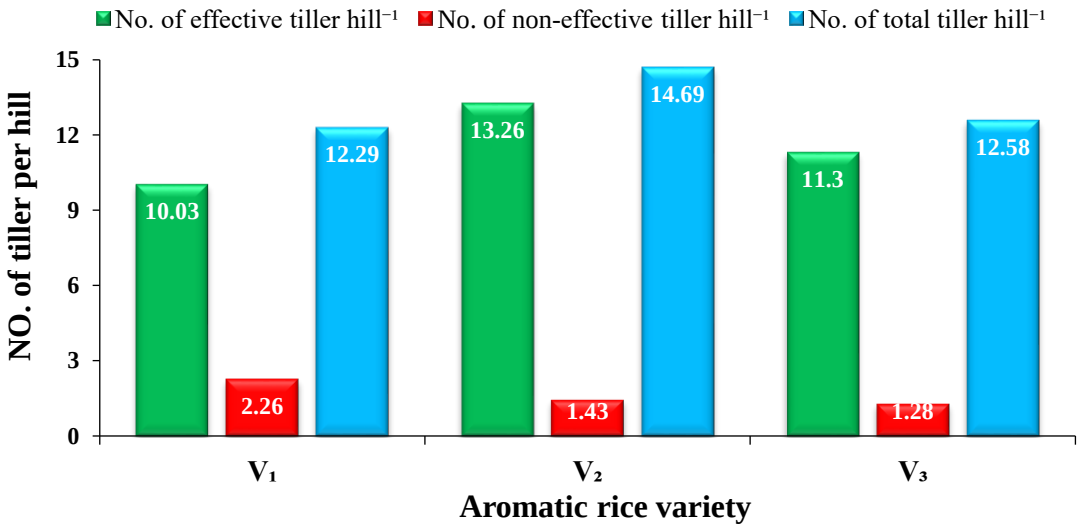
H_0 – Control, H_1 – Pyrazosulfuron ethyl 70% WG @ 15 g ha^{-1}, H_2 – Bensulfuron methyl 10% WP @ 50 g ha^{-1} and H_3 – Metsulfuron methyl 20% WP @ 20 g ha^{-1}

Figure 4: Effect of herbicidal weed control on no. of effective tillers, non-effective tillers and total tillers hill^{-1} of aromatic rice variety ($LSD_{0.05}$ = 0.98, 0.02 and 0.95, for effective tillers hill^{-1}, non-effective tillers hill^{-1} and total tillers hill^{-1}, respectively)

4.2.2.2 Effect of variety

Productive tillers unit^{-1}area determine the final yield of rice. This is why it is said that the higher the effective tillers, the higher the yield. It was evident from Figure 5 and Appendix V that variety had significant effect on numbers of effective tiller hill^{-1}. BRRI Dhan70 (V_2) produced highest number (13.26) and BRRI Dhan38 (V_1) produced lowest number (10.03) of productive tiller. Similar results were observed by Jones *et al.* (1996). The same result was reported by Peng *et al.* (1996). He found a negative correlation between maximum tiller number and percentage of productive tillers. On the other hand, the dissimilar

result was reported by Hossen (2014). He found that BRRI dhan38 was maximum effective tillers hill^{-1}.



V_1 – BRRI dhan38, V_2 – BRRI dhan70 and V_3 – BRRI dhan80

Figure 5: Effect of varietal performance on no. of effective tillers, non-effective tillers and total tillers hill^{-1} of aromatic rice variety ($LSD_{0.05}$ = 1.12, 0.08 and 1.13, for effective tillers, non-effective tillers and total tillers hill^{-1}, respectively)

4.2.2.3 Interaction effect of herbicidal weed control and variety

Effective tiller hill^{-1} was significantly affected by the interaction of weed control treatment with variety (Table 6 and Appendix V). The highest effective tillers (16.80) were obtained from the combination of Metsulfuron methyl 20% WP @ 20 g ha^{-1}with BRRI dhan70 (H_3V_2). The second highest effective tillers (13.31) were obtained from the combination of H_3V_3 treatment which was statistically similar with H_2V_2 (13.23). The lowest (7.77) was found from the combination of control with BRRI dhan38 (H_0V_1). Similar findings were reported by Khan and Tarique (2011), Hassan *et al.* (2010) and Ashraf *et al.* (2006) who stated that effective tillers hill^{-1} varied due to various varieties and weed control treatments.

Table 6. Interaction effect of herbicidal weed control and varietal performance on no. of effective tillers, non-effective tillers and total tillers hill^{-1} of aromatic rice variety

Treatment Combination	No. of effective tiller hill^{-1}	No. of non-effective tiller hill^{-1}	No. of total tiller hill^{-1}
H_0V_1	7.77 e	2.78 a	13.95 b
H_0V_2	10.84 cd	2.00 b	14.18 b
H_0V_3	9.03 de	1.91 b	14.21 b
H_1V_1	11.17 cd	2.60 a	10.40 d
H_1V_2	12.18 c	1.35 cd	12.20 bc
H_1V_3	12.30 c	1.16 d	10.16 d
H_2V_1	10.67 d	1.96 b	12.63 bc
H_2V_2	13.23 b	1.12 d	14.35 b
H_2V_3	10.54 d	1.05 d	11.59 cd
H_3V_1	10.52 d	1.70 bc	12.22 c
H_3V_2	16.80 a	1.26 cd	18.06 a
H_3V_3	13.31b	1.00 d	14.31 b
LSD $_{(0.05)}$	2.20	0.38	2.96
CV (%)	8.35	10.91	7.40

In a column, means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly as per 0.05 level of probability
H_0 – Control, H_1 – Pyrazosulfuron ethyl 70% WG @ 15 g ha^{-1}, H_2 – Bensulfuron methyl 10% WP @ 50 g ha^{-1}and H_3 – Metsulfuron methyl 20% WP @ 20 g ha^{-1}
V_1 – BRRI dhan38, V_2 – BRRI dhan70 and V_3 – BRRI dhan80

4.2.3 Number of non-effective tillers hill^{-1}

4.2.3.1 Effect of herbicidal weed control

The number of non-effective tillers hill^{-1} varied significantly due to the application of different herbicides (Figure 4 and Appendix V). The maximum number of non-effective tillers hill^{-1} (2.23) was obtained from H_0 (control, no herbicide used, no weeding) treatment. The minimum number of non-effective tillers hill^{-1} (1.32) was obtained from H_3 (Metsulfuron methyl 20% WP @ 20 g

ha^{-1} treatment which was statistically similar (1.37) with H_2 (Bensulfuron methyl 10% WP @ 50 g ha^{-1}). Different weed management treatment kept the land clear and soil was aerated which facilitated the crop for absorption of greater amount plant nutrient, moisture and greater reception of solar radiation for growth resulted in lower number of non-effective tillers $hill^{-1}$.

4.2.3.2 Effect of variety

It is evident that, higher non-effective tillers $hill^{-1}$ confirm lower yield. It was evident from Figure 5 and Appendix V that variety had significant effect on numbers of non-effective tiller $hill^{-1}$. BRRI dhan38 (V_1) produced higher number (2.26) and BRRI dhan80 (V_3) produced lower number (1.28) of non-effective tiller $hill^{-1}$ which was statistically similar with BRRI dhan70 (1.43).

4.2.3.3 Interaction effect of herbicidal weed control and variety

Non-effective tillers $hill^{-1}$ were significantly affected by the interaction of weed control treatment with variety (Table 6 and Appendix V). The highest non-effective tiller (2.78) was obtained from the combination of control (no herbicide used, no weeding) with BRRI dhan38 (H_0V_1) treatment which was statistically similar with the combination of H_1V_1 Pyrazosulfuron ethyl 70% WG @ 15 g ha^{-1} with BRRI dhan38 (2.60). The lowest (1.00) was found from the combination of Metsulfuron methyl 20% WP @ 20 g ha^{-1} with BRRI dhan80 (H_3V_3) which was statistically similar with H_2V_3 (1.05) followed by H_2V_2 (1.12) and H_1V_3 (1.16).

4.2.4 Number of total tillers $hill^{-1}$

4.2.4.1 Effect of herbicidal weed control

The number of total tillers $hill^{-1}$ was significantly influenced by weed control method at 45 DAT of crop growth (Figure 4 and Appendix V). Weed control by (H_3) pre-emergence herbicide Metsulfuron methyl 20% WP @ 20 g ha^{-1} was achieved maximum tiller (14.86) and the second highest tiller (13.56) was observed from (H_1) Pyrazosulfuron ethyl 70% WG @ 15 g ha^{-1}. H_0 (no herbicide

used, no weeding) control treatment gave the lowest (11.43) tiller at harvest. This result was in agreement with the findings of Al-Mamun *et al.* (2011), Bhuiyan *et al.* (2011), Mamun *et al.* (2011), Ali *et al.* (2010), Gnanavel and Anbhazhagan (2010) and Kabir *et al.* (2008).

4.2.4.2 Effect of variety

The number of total tillers hill^{-1} was significantly influenced by variety at 45 DAT of crop growth (Figure 5 and Appendix V). BRRI dhan70 (V_2) produced the maximum (14.69) tiller, then decreased to maturity with advancement to age, and BRRI dhan38 (V_1) minimum (12.27) tiller production was also observed, which was statistically similar to BRRI dhan80 (12.58). This revealed that during the reproductive and ripening phases the rate of tiller mortality exceeded the tiller production rate (Roy and Satter, 1992). Variable effect of variety on number of total tillers hill^{-1} was also reported by Hussain *et al*. (1989) who noticed that number of total tillers hill^{-1} differed among the varieties.

4.2.4.3 Interaction effect of herbicidal weed control and variety

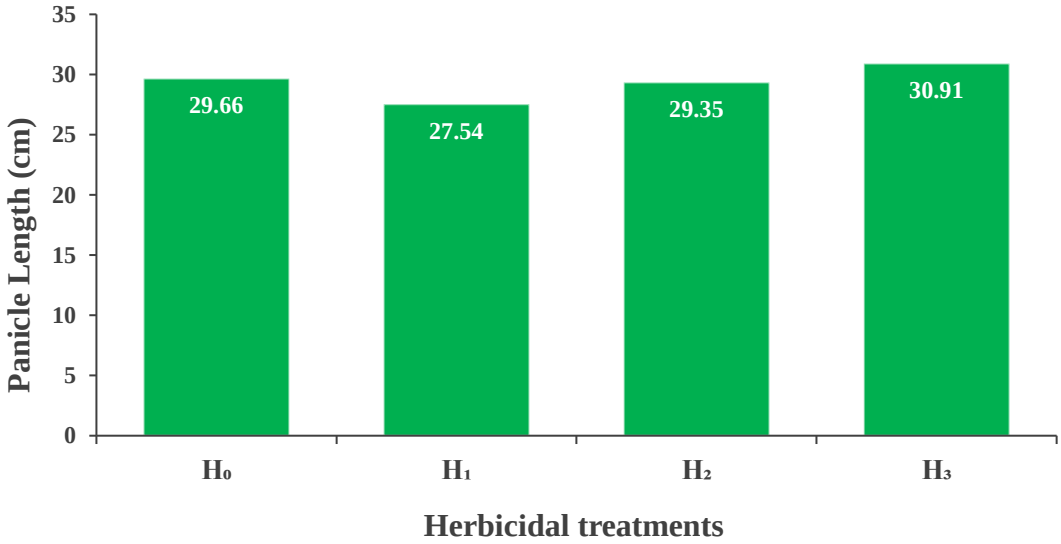
The number of total tillers hill^{-1} was significantly affected by the interaction of weed control and variety (Table 6). Pre-emergence herbicide Metsulfuron methyl 20% WP @ 20 g ha^{-1} and BRRI dhan70 (H_3V_2) treatment combination was achieved maximum (18.06) tiller and the minimum (10.55) tiller production was observed from control with BRRI dhan38 (H_0V_1) which was statistical similar with H_0V_3(10.94).

4.2.5 Panicle length (cm)

4.2.5.1 Effect of herbicidal weed control

The panicle length varied significantly due to weed control treatments (Figure 6 and Appendix VI). It was observed that the longest panicle (30.91 cm) was observed from the treatment H_3 (Metsulfuron methyl 20% WP @ 20 g ha^{-1}). The shortest (27.54 cm) panicle length was observed from Pyrazosulfuron ethyl 70%

WG @ 15 g ha^{-1}treatment (H_1). This confirms the report of Khan and Tarique (2011) and Hasanuzzaman *et al.* (2008) who observed that panicle length was differed due to different weed control treatments.

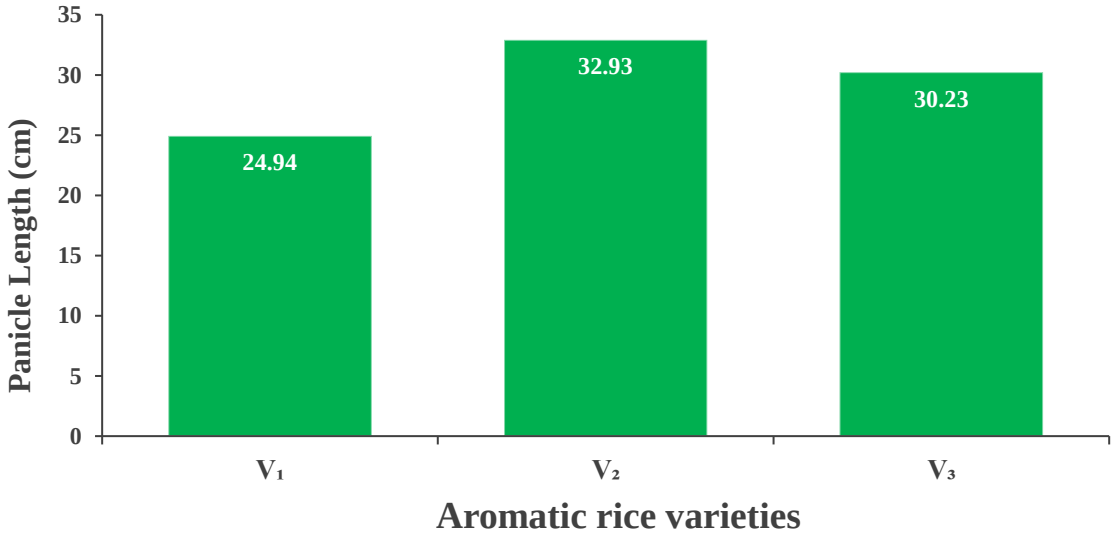


H_0 – Control, H_1 – Pyrazosulfuron ethyl 70% WG @ 15 g ha^{-1}, H_2 – Bensulfuron methyl 10% WP @ 50 g $ha^{-1}$and H_3 – Metsulfuron methyl 20% WP @ 20 g ha^{-1}

Figure 6: Effect of herbicidal weed control on panicle length of aromatic rice variety ($LSD_{0.05}$ = 0.08, at harvesting time)

4.2.5.2 Effect of variety

The panicle length varied significantly due to variety (Figure 7 and Appendix VI). It was observed that BRRI dhan70 (V_2) produced significantly longer (32.93 cm) panicle. The second longer panicle length (30.23 cm) was measured from BRRI dhan80 (V_3) and the shortest panicle length (24.94 cm) was measured from BRRI dhan38 (V_1). This confirms the report of Ahmed *et al.* (1997) and Idris and Matin (1990) who showed that panicle length was differed among the varieties.



V_1 – BRRI dhan38, V_2 – BRRI dhan70 and V_3 – BRRI dhan80

Figure 7: Effect of varietal performance on panicle length of aromatic rice variety ($LSD_{0.05}$ = 0.60, at harvesting time)

4.2.5.3 Interaction effect of herbicidal weed control and variety

Panicle length was significantly affected by the interaction of herbicidal weed control and variety (Table 7 and Appendix VI). The longest (34.81 cm) panicle was observed from the combination of Metsulfuron methyl 20% WP @ 20 g ha^{-1} with BRRI dhan70 (H_3V_2). Second highest panicle length (33.63 cm) was obtained from the combination of control (no herbicide used, no weeding) with BRRI dhan70 (H_0V_2) and the shorter (22.63 cm) was found from the combination of Pyrazosulfuron ethyl 70% WG @ 15 g ha^{-1} and BRRI dhan38 (H_1V_1).

Table 7. Interaction effect of herbicidal weed control and varietal performance on panicle length (cm), no. of filed grains panicle^{-1}, unfilled grains panicle^{-1} and total grains panicle^{-1} of aromatic rice

Treatment combination	Panicle length (cm)	No. of filled grains panicle^{-1}	No. of unfilled grains panicle^{-1}	No. of total grains panicle^{-1}
H_0V_1	25.20 e	76.69 c	18.21 a	94.90 d
H_0V_2	33.63 b	68.05 d	14.15 d	82.20 e
H_0V_3	30.14 d	61.33 e	16.29 b	77.62 f
H_1V_1	22.63 f	78.42 c	18.01 a	96.43 cd
H_1V_2	30.70 d	82.00 c	15.89 c	97.79 cd
H_1V_3	29.29 de	80.06 c	14.52 d	95.85 d
H_2V_1	25.24 e	81.42 c	17.14 b	98.56 bc
H_2V_2	32.57 bc	88.47 b	12.41 de	100.61 ab
H_2V_3	30.24 d	90.73 b	15.32 c	106.05 a
H_3V_1	26.70 e	88.37 b	15.10 c	103.47 ab
H_3V_2	34.81 a	98.46 a	11.03 f	109.49 a
H_3V_3	31.23 c	91.50 b	13.41d	104.91 ab
LSD $_{(0.05)}$	0.60	2.52	0.16	0.15
CV (%)	10.19	6.68	8.66	11.09

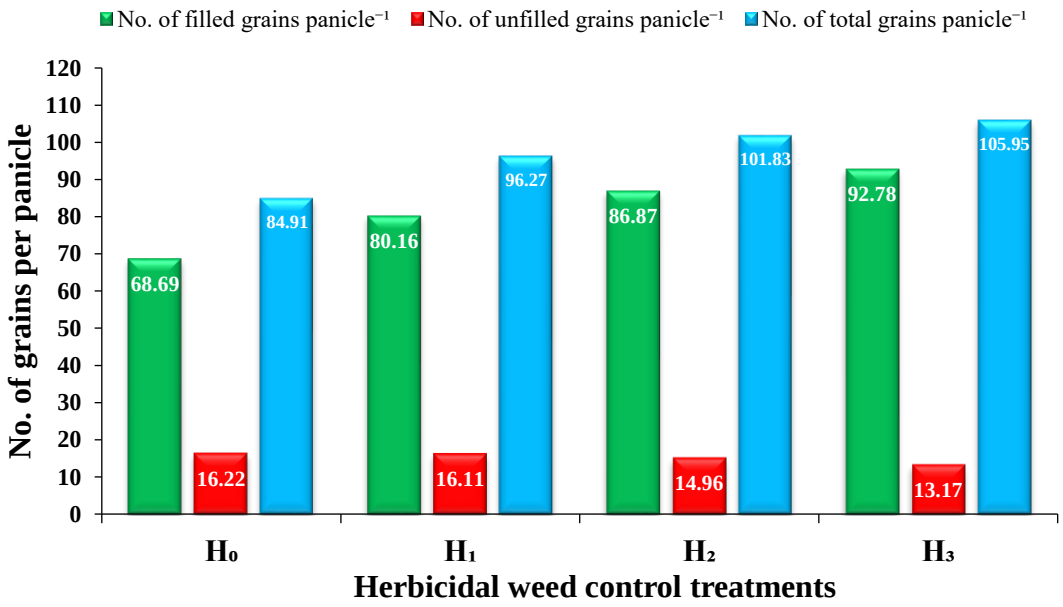
In a column, means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly as per 0.05 level of probability
H_0 – Control, H_1 – Pyrazosulfuron ethyl 70% WG @ 15 g ha^{-1}, H_2 – Bensulfuron methyl 10% WP @ 50 g ha^{-1} and H_3 – Metsulfuron methyl 20% WP @ 20 g ha^{-1}
V_1 – BRRI dhan38, V_2 – BRRI dhan70 and V_3 – BRRI dhan80

4.2.6 Number of filled grains panicle^{-1}

4.2.6.1 Effect of herbicidal weed control

Significant variation was found in filled grains panicle^{-1} due to the application of different herbicides on the aromatic rice field (Figure 10 and Appendix VI). The maximum number of filled grain panicle^{-1} (92.78) was recorded from (H_3) Metsulfuron methyl 20% WP @ 20 g ha^{-1} treatments. The minimum number of filled grain panicle^{-1} (68.69) was obtained from control (H_0, no herbicide used,

no weeding) treatment. Similar results were reported by Hasanuzzaman *et al.* (2008) and Salam *et al.* (2010) who showed that application of herbicide contributed mainly increasing the number of grains panicle^{-1}. However, similar findings were stated by Karim and Ferdous (2010) who revealed that the number of filled grains panicle^{-1} was negatively related to weed density.

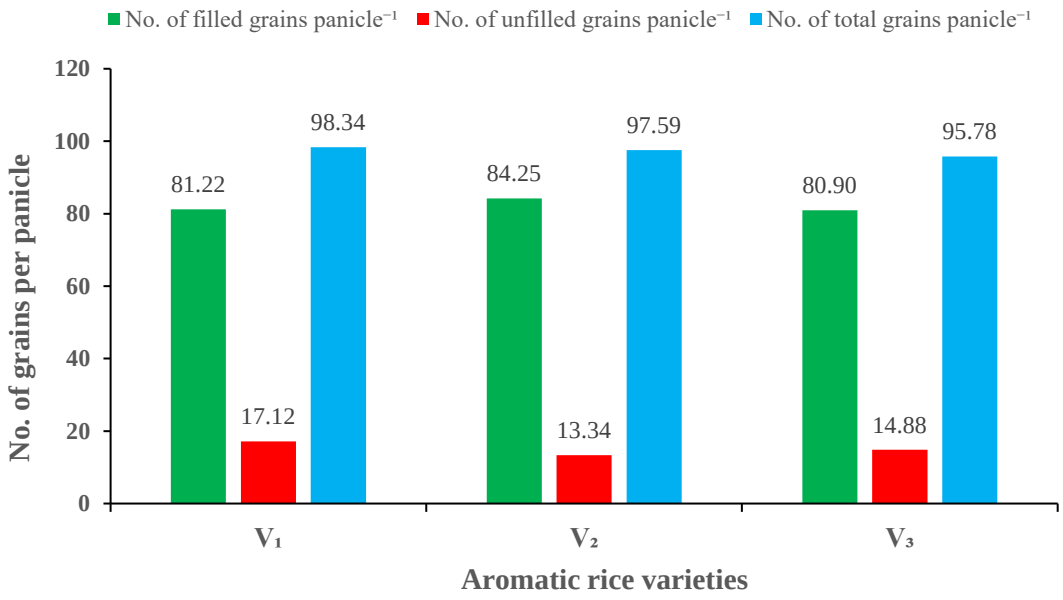


H_0 – Control, H_1 – Pyrazosulfuron ethyl 70% WG @ 15 g ha^{-1}, H_2 – Bensulfuron methyl 10% WP @ 50 g ha^{-1} and H_3 – Metsulfuron methyl 20% WP @ 20 g ha^{-1}

Figure 8: Effect of herbicidal weed control on no. of filled grains, unfilled grains and total grains panicle^{-1} of aromatic rice variety ($LSD_{0.05}$= 4.45, 0.15 and 0.11 respectively, at harvesting time)

4.2.6.2 Effect of variety

Significant variation was found in filled grains panicle^{-1} due to the varieties in the aromatic rice (Figure 11 and Appendix VI). The maximum number of filled grain panicle^{-1} (84.25) was recorded from V_2 (BRRI dhan70) treatment and the minimum number of filled grain panicle^{-1} (80.90) was obtained from V_3 (BRRI dhan80) treatment. These results were in agreement with Ahmed *et al.* (1997) who reported that percent filled grain was the highest in Nizersail (a local variety) followed by BR25 and the lowest in BR11 and BR23.



V_1 – BRRI dhan38, V_2 – BRRI dhan70 and V_3 – BRRI dhan80

Figure 9: Effect of varietal performance on no. filled grains, unfilled grains and total grains panicle^{-1} of aromatic rice variety ($LSD_{0.05}$ = 2.52, 0.16 and 0.15, respectively, at harvesting time)

4.2.6.3 Interaction effect of herbicidal weed control and variety

Significant variation was found in filled grains panicle^{-1} due to the application of different herbicides with varieties in the aromatic rice (Table 8 and Appendix VI). The maximum number of filled grain panicle^{-1} (98.46) was recorded from the interaction effect of H_3V_2 (Metsulfuron methyl 20% WP @ 20 g ha^{-1} with BRRI dhan70) treatment. The second maximum was found (91.50) H_3V_3 (Metsulfuron methyl 20% WP @ 20 g ha^{-1} with BRRI dhan80) treatment which was statistically similar H_2V_3 (90.73), followed by H_2V_2 (88.47) and H_3V_1 (88.37) treatments. The minimum number of filled grain panicle^{-1} (61.33) was obtained from H_0V_3 control (no herbicide use, no weeding) with BRRI dhan80 treatment. These results were in agreement with the findings of Salam *et al.* (2010) who showed that the increased yield in *boro* rice (Binadhan-5) is due to the application of herbicide contributed mainly from increasing the number of panicles hill^{-1} and number of grain panicle^{-1}. Similar results were also shown by

Ashraf *et al.* (2006) who stated that in transplanted rice (cv. Basmati-2000) the highest number of grains per panicle was 135.50 during the second year in the case of hand weeding. However, dissimilar results were observed by Karim and Ferdous (2010) who stated that the number of filled grains panicle^{-1} was negatively related to weed density in transplanted *aus* rice cv. BR26.

4.2.7 Number of unfilled grains panicle^{-1}

4.2.7.1 Effect of herbicidal weed control

Unfilled grains panicle^{-1} varied significantly due to the application of different herbicides (Figure 10 and Appendix VI). The maximum number of unfilled grains panicle^{-1} (16.11) was recorded from H_1 (Pyrazosulfuron ethyl 70% WG @ 15 g ha^{-1}) treatment which was statistically (16.22) similar with H_0 (Control, no herbicide used, no weeding) The minimum number of unfilled grain panicle^{-1} (13.17) was obtained from H_3 (Metsulfuron methyl 20% WP @ 20 g ha^{-1}) treatment. Rafiquddualla (1999) observed that maximum non-effective tillers hill^{-1} and sterile grains were found from the no weeding regimes.

4.2.7.2 Effect of variety

Significant variation was obtained in unfilled grain due to the effect of variety (Figure 11 and Appendix VI). BRRI dhan38 (V_1) produced highest unfilled grain (17.12). The second highest unfilled grain (14.88) was obtained from BRRI dhan80 (V_3) and the lowest unfilled grain (13.34) from BRRI dhan70 (V_2). BRRI dhan38 produced 33.76% highest unfilled grain than BRRI dhan70. Similar findings were reported by Ahmed *et al.* (1997).

4.2.7.3 Interaction effect of herbicidal weed control and variety

Significant variation was obtained in unfilled grain due to the interaction effect of weed control method and variety shown in Table 8 and Appendix VI. Interaction effect of control (no herbicide used, no weeding) with BRRI dhan38 (H_0V_1) gave highest unfilled grain (18.21) which was statistically similar with Pyrazosulfuron ethyl 70% WG @ 15 g ha^{-1} with BRRI dhan38 (H_1V_1) treatment.

The lowest unfilled grain (11.03) was found from the interaction effect of Metsulfuron methyl 20% WP @ 20 g ha^{-1} with BRRI dhan70 (H_3V_2).

4.2.8 Number of total grains panicle^{-1}

4.2.8.1 Effect of herbicidal weed control

Number of total grains panicle^{-1} varied significantly due to the application of different herbicides in aromatic rice (Figure 10 and Appendix VI). The maximum number of total grains panicle^{-1} (105.95) was recorded from H_3 Metsulfuron methyl 20% WP @ 20 g ha^{-1} treatment. The minimum number (84.91) of total grains panicle^{-1} was obtained from H_0 (Control, no herbicide use, no weeding) treatment. Geethu *et al.* (2014) reported that plants were affected by weed competition resulting reduce the total number of grains panicle^{-1}.

4.2.8.2 Effect of variety

Number of total grains panicle^{-1} varied significantly due to the varieties in aromatic rice field (Figure 11 and Appendix VI). The maximum number of total grains panicle^{-1} (98.34) was recorded from V_1 (BRRI dhan38) treatment which was statistically similar with V_2 (97.52) BRRI dhan70. The minimum number (95.78) of total grains panicle^{-1} was obtained from V_3 (BRRI dhan80) treatment.

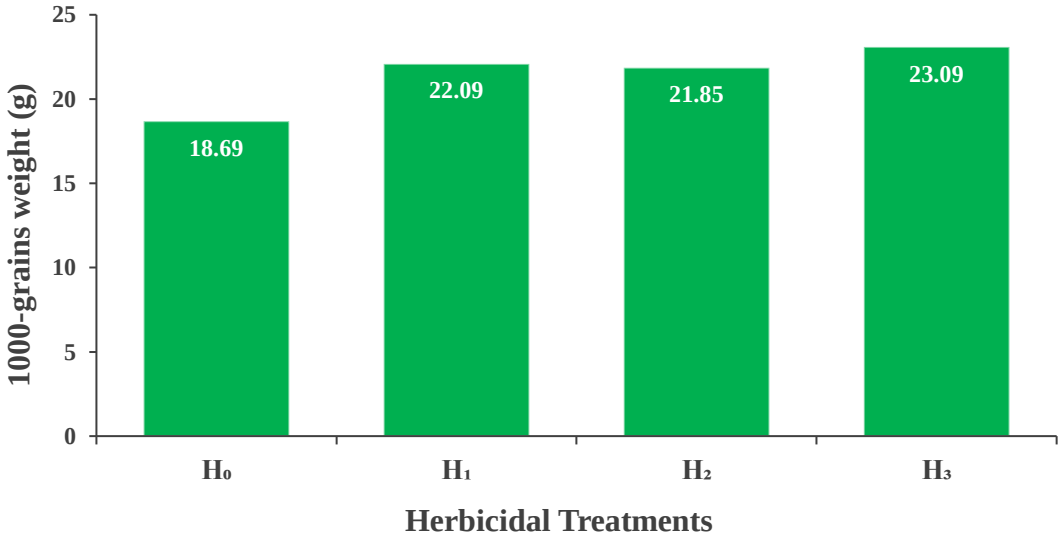
4.2.8.3 Interaction effect of herbicidal weed control and variety

Significant variation was obtained in the number of total filled grain panicle^{-1} due to the interaction effect of weed control method and variety (Table 8 and Appendix VI). Interaction effect of Metsulfuron methyl 20% WP @ 20 g ha^{-1} with BRRI dhan70 (H_3V_2) gave highest total filled grain panicle^{-1} (109.50) which was at par with the combination of H_2V_3 (Bensulfuron methyl 10% WP @ 50 g ha^{-1} with BRRI dhan80). The lowest total filled grain panicle^{-1} (77.62) was found from the interaction effect of control (no herbicide used, no weeding) with BRRI dhan80 (H_0V_3).

4.2.9 1000-grains weight (g)

4.2.9.1 Effect of herbicidal weed control

Effect of herbicidal weed control showed significant variation in 1000-seeds weight of rice. The result revealed that Metsulfuron methyl 20% WP @ 20 g ha^{-1} (H_3) gave the highest 1000-grains weight (23.09 g) Figure 8 and Appendix VI. The lowest 1000-grains weight (18.69 g) was found from control (H_0, no weeding, no herbicide used). This finding was in agreement with Khan and Tarique (2011), Hassan *et al.* (2010) and Raju *et al.* (2003) who showed that weeding regime had significant effect on 1000-grains weight of rice. But this result was dissimilar with the findings of Nahar *et al.* (2010) and Karim and Ferdous (2010) who observed that 1000 grain weight was negatively related to weed density.

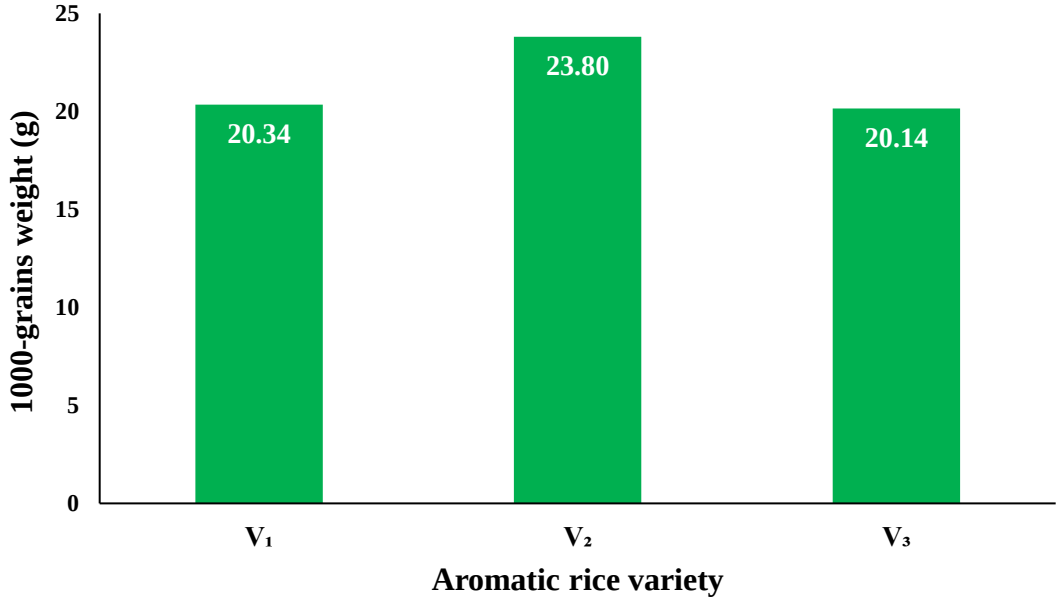


H_0 – Control, H_1 – Pyrazosulfuron ethyl 70% WG @ 15 g ha^{-1}, H_2 – Bensulfuron methyl 10% WP @ 50 g ha^{-1} and H_3 – Metsulfuron methyl 20% WP @ 20 g ha^{-1}

Figure 10: Effect of herbicidal weed control on 1000-grains weight (g) of aromatic rice variety ($LSD_{0.05}$ = 0.19, at harvesting time)

4.2.9.2 Effect of variety

Weight of 1000 grains showed significant variation among the different varieties. BRRI dhan70 produced highest 1000-grains weight (23.80 g). The second highest 1000-grains weight (20.34 g) was found in BRRI dhan38 (Figure 9 and Appendix VI). The lowest 1000-grains weight (20.14 g) was obtained from BRRI dhan80. Similar findings were reported by Hossain *et al.* (2007).



V_1 – BRRI dhan38, V_2 – BRRI dhan70 and V_3 – BRRI dhan80

Figure 11: Effect of varietal performance on 1000-grains weight (g) of aromatic rice variety ($LSD_{0.05}$ = 0.16, at harvesting time)

4.2.9.3 Interaction effect of herbicidal weed control and variety

Interaction effect of herbicidal weed control and variety showed significant variation in 1000-grains weight (Table 7 and Appendix VI). The highest grain weight (26.97 g) was found from the interaction effect of Metsulfuron methyl 20% WP @ 20 g ha^{-1} with BRRI dhan70 (H_3V_2) which was statistically similar with (25.82) the interaction effect of Bensulfuron methyl 10% WP @ 50 g ha^{-1} with BRRI dhan70 (H_2V_2). The lowest grain weight (16.15 g) was found with the interaction effect of control (no herbicide use, no weeding) with BRRI

dhan38 (H_0V_1). This result supports the findings of Hassan *et al.* (2010) who reported that weight of 1000 grains varied significantly due to various weed control treatments in transplant *aman* rice cv. BRRI dhan41. However, this result was not in agreement with Nahar *et al.* (2010) who found that weeding regime had significant effect on all the parameters except 1000-grain weight in transplant *aman* rice cv. BRRI dhan41.

Table 8. Interaction effect of herbicidal weed control and varietal performance on 1000-grains weight of aromatic rice

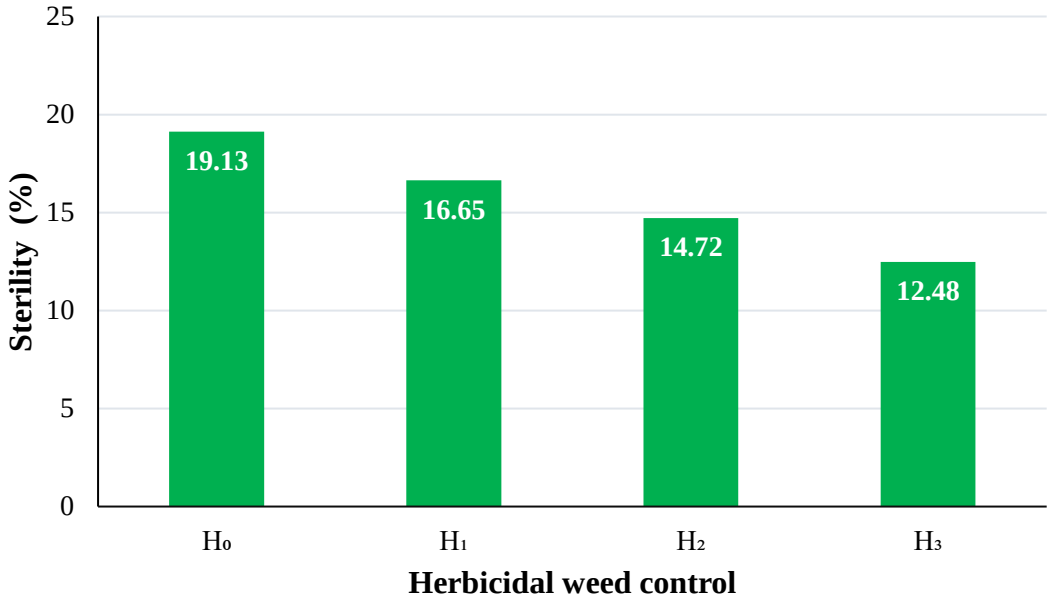
Treatment combination	1000-grains weight (g)
H_0V_1	16.15 e
H_0V_2	19.24 cd
H_0V_3	20.69 c
H_1V_1	24.77 ab
H_1V_2	23.16 b
H_1V_3	18.26 d
H_2V_1	19.60 cd
H_2V_2	25.82 a
H_2V_3	20.12 c
H_3V_1	20.82 c
H_3V_2	26.97 a
H_3V_3	21.47 bc
LSD (0.05)	0.16
CV (%)	11.41

In a column, means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly as per 0.05 level of probability
H_0 – Control, H_1 – Pyrazosulfuron ethyl 70% WG @ 15 g ha^{-1}, H_2 – Bensulfuron methyl 10% WP @ 50 g ha^{-1} and H_3 – Metsulfuron methyl 20% WP @ 20 g ha^{-1}
V_1 – BRRI dhan38, V_2 – BRRI dhan70 and V_3 – BRRI dhan80

4.2.10 Sterility (%)

4.2.10.1 Effect of herbicidal weed control

The sterility (%) varied significantly due to the application of different doses of herbicides in the aromatic rice (Figure 12 and Appendix VI). The maximum sterility (19.13 %) was founded from H_0 (control, no herbicideused, no weeding) treatment. On the other hand, the minimum sterility (12.48 %) was obtained from H_3 (Metsulfuron methyl 20% @ 20 g ha^{-1}).

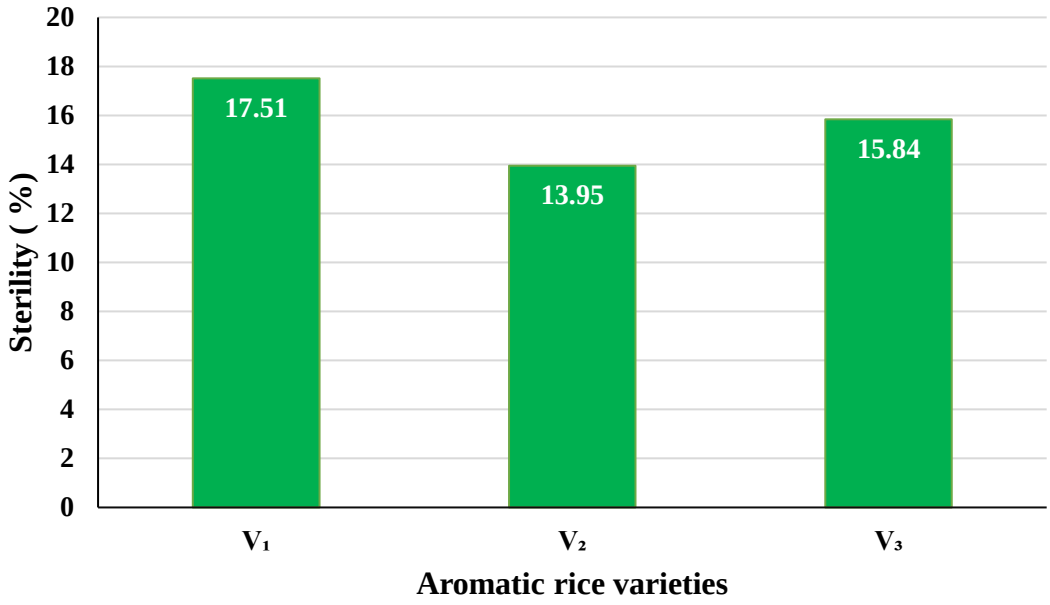


H_0 – Control, H_1 – Pyrazosulfuron ethyl 70% WG @ 15 g ha^{-1}, H_2 – Bensulfuron methyl 10% WP @ 50 g ha^{-1} and H_3 – Metsulfuron methyl 20% WP @ 20 g ha^{-1}

Figure 12: Effect of herbicidal weed control on sterility (%) of aromatic rice variety ($LSD_{0.05}$ = 0.46, at harvesting time)

4.2.10.2 Effect of variety

The sterility (%) varied significantly for varietal variation throughout of the growoing period (Figure 13 and Appendix VI). At harvesting time, BRRI dhan38 (V_1) scored the maximum sterility (17.51 %). The minimum sterility (13.95 %) was observed for BRRI dhan70 (V_2).



V_1 – BRRI dhan38, V_2 – BRRI dhan70 and V_3 – BRRI dhan80

Figure 13: Effect of varietal performance on sterility (%) of aromatic rice variety ($LSD_{0.05}$ = 0.15, at harvesting time)

4.2.10.3 Interaction effect of herbicidal weed control and variety

Sterility (%) was significantly affected by the interaction of weed control and variety (Table 9). At harvesting time, the maximum sterility (20.99 %) was recorded from the combination of control (no herbicide used, no weeding) with BRRI dhan80 (H_0V_3) and the minimum (10.07 %) was obtained from Metsulfuron methyl 20% WP @ 20 g ha^{-1} with BRRI dhan70 (H_3V_2).

Table 9. Interaction effect of herbicidal weed control and varietal performance on sterility (%) of aromatic rice variety

Treatment combination	Sterility (%)
H_0V_1	19.18 b
H_0V_2	17.21 d
H_0V_3	20.99 a
H_1V_1	18.68 bc
H_1V_2	16.14 d
H_1V_3	15.14 d
H_2V_1	17.39d
H_2V_2	12.33 ef
H_2V_3	14.44 e
H_3V_1	14.59 e
H_3V_2	10.07 g
H_3V_3	12.78 ef
LSD (0.05)	0.17
CV (%)	8.35

In a column, means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly as per 0.05 level of probability
H_0 – Control, H_1 – Pyrazosulfuron ethyl 70% WG @ 15 g ha^{-1}, H_2 – Bensulfuron methyl 10% WP @ 50 g ha^{-1} and H_3 – Metsulfuron methyl 20% WP @ 20 g ha^{-1}
V_1 – BRRI dhan38, V_2 – BRRI dhan70 and V_3 – BRRI dhan80

4.2.11 Grain yield (t ha^{-1})

4.2.11.1 Effect of herbicidal weed control

Rice grain yield (t ha^{-1}) varied significantly due to the application of different herbicides in the aromatic rice (Table 10 and Appendix VII). The maximum grain yield (5.18 t ha^{-1}) was recorded from H_3 (Metsulfuron methyl 20% WP @ 20 g ha^{-1}) treatment. On the other hand, the minimum grain yield (3.94 t ha^{-1}) was obtained from H_0 (no herbicide used, no weeding). Chowdhury *et al.* (1995) reported that the highest grain yield was produced from weed free plot as a result

of less competition with weeds. The similar findings were reported by Al-Mamun *et al.* (2011), Bhuiyan *et al.* (2011), Bhuiyan *et al.* (2011), Khan and Tarique (2011), Mamun *et al.* (2011), Shultana *et al.* (2011), Ali *et al.* (2010), Bhuiyan *et al.* (2010), Gnanavel and Anbhazhagan (2010), Islam *et al.* (2010), Nahar *et al.* (2010), Salam *et al.* (2010) and Pacanoski and Glatkova (2009) who observed that application of chemical herbicides significantly increases grain yield of rice.

Table 10. Effect of herbicidal weed control on yield (t ha^{-1}) and harvest index (%) of aromatic rice variety

Herbicidal weed control	Grain yield (t ha^{-1})	Straw yield (t ha^{-1})	Biological yield (t ha^{-1})	Harvest index (%)
H_0	3.94 c	5.42 a	9.55 c	41.93 d
H_1	4.54 b	5.16 c	9.70 c	46.68 c
H_2	4.89 b	5.31 b	10.21 b	47.83 b
H_3	5.18 a	5.38 ab	10.57 a	48.98 a
LSD $_{(0.05)}$	0.05	0.20	0.18	0.95
CV (%)	8.79	7.91	10.96	9.90

In a column, means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly as per 0.05 level of probability
H_0 – Control, H_1 – Pyrazosulfuron ethyl 70% WG @ 15 g ha^{-1}, H_2 – Bensulfuron methyl 10% WP @ 50 g ha^{-1} and H_3 – Metsulfuron methyl 20% WP @ 20 g ha^{-1}

4.2.11.2 Effect of variety

Rice grain yield (t ha^{-1}) varied significantly for different varieties (Table 11 and Appendix VII). The highest grain yield (5.21 t ha^{-1}) was recorded by BRRI dhan70 (V_2). The second highest grain yield (4.71 t ha^{-1}) was recorded from BRRI dhan80 (V_3). The lowest grain yield (4.00 t ha^{-1}) was recorded from BRRI dhan38 (V_1). Similar results were found by Reza *et al.* (2010) who stated that Pajam (a local variety) produced the higher grain yield (4.0 t ha^{-1}) than BRRI dhan28 (2.79 t ha^{-1}).

Table 11. Effect of varietal performance on yield and harvest index (%) of aromatic rice variety

Aromatic rice varieties	Grain yield (t ha^{-1})	Straw yield (t ha^{-1})	Biological yield (t ha^{-1})	Harvest index (%)
V_1	4.00 c	5.43 a	9.43 c	42.24 c
V_2	5.21 a	5.21 b	10.44 a	49.81 a
V_3	4.71 b	5.29 b	10.00 b	47.01 b
LSD $_{(0.05)}$	0.06	0.15	0.22	0.63
CV (%)	9.79	6.91	10.26	7.90

In a column, means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly as per 0.05 level of probability
V_1 – BRRI dhan38, V_2 – BRRI dhan70 and V_3 – BRRI dhan80

4.2.11.3 Interaction effect of herbicidal weed control and variety

Rice grain yield (t ha^{-1}) varied significantly due to different weed control treatment and varietal combinations (Table 12 and Appendix VII). The highest grain yield (5.65 t ha^{-1}) was recorded from Metsulfuron methyl 20% WP @ 20 g ha^{-1} with BRRI dhan70 combination (H_3V_2). The lowest grain yield (3.07 t ha^{-1}) was recorded from control (no herbicide used, no weeding) with BRRI dhan38 treatment combination (H_0V_1). This result is in agreement with Al-Mamun *et al.* (2011) who reported that the highest grain yield (6.96 t ha^{-1}) was obtained from Surjamoni when treated with Bouncer 10WP @ 150 g ha^{-1}, which was 49% higher than control. BRRI dhan29 also produced the highest grain yield when treated with same treatment, which was 37% higher than control. Ali *et al.* (2010) found that among the weed control treatments Pretilachlor + one hand weeding at 40 DAT performed best for contribution to the highest grain yield (3.60 t ha^{-1}). Singh and Kumar (1999) reported that the lowest grain yield was observed in the unweeded control in the scented rice variety Pusa Basmati−1. Similar results were also reported by Islam *et al.* (2010), Nahar *et al.* (2010), Salam *et al.* (2010), Gnanavel and Anbhazhagan (2010) and Bijon (2004).

4.2.12 Straw yield (t ha^{-1})

4.2.12.1 Effect of herbicidal weed control

Rice straw yield (t ha^{-1}) varied significantly due to the application of different herbicides in the aromatic rice (Table 10 and Appendix VII). The maximum straw yield (5.42 t ha^{-1}) was recorded from H_0 (No herbicide used, no weeding) treatment. The minimum straw yield per hectare (5.16 t ha^{-1}) was obtained from H_1 (Pyrozosulfuran ethyl 70% WG @ 15 g ha^{-1}) treatment. Rafiquddaulla (1999) observed that the weed dry weight was significantly affected by the weeding regimes.

4.2.12.2 Effect of variety

There observed a significant variation for straw yield (t ha^{-1}) due to varietal variation (Table 11 and Appendix VII). BRRI dhan38 (V_1) recorded the highest straw yield (5.43 t ha^{-1}) and BRRI dhan70 (5.21 t ha^{-1}) recorded the lowest straw yield which was statistically similar with BRRI dhan80 (V_3, 5.29 t ha^{-1}). Similar findings were also reported by Hassan *et al.* (2010).

Table 12. Interaction effect of herbicidal weed control and varietal performance yield, and harvest index (%) of aromatic rice variety

Treatment combination	Grain yield (t ha^{-1})	Straw yield (t ha^{-1})	Biological yield (t ha^{-1})	Harvest index (%)
H_0V_1	3.07 e	5.70 a	8.77 d	35.00 d
H_0V_2	4.76 c	5.20 c	9.96 c	47.79 bc
H_0V_3	4.00 cd	5.30 bc	9.30 c	43.01 c
H_1V_1	4.00 cd	5.40 b	9.40 c	42.55 c
H_1V_2	5.08 b	4.95 d	10.03 bc	50.64 b
H_1V_3	4.53 c	5.14 c	9.67 c	46.85 bc
H_2V_1	4.28 c	5.20 c	9.48 c	45.15 c
H_2V_2	5.33 ab	5.40 b	10.73 ab	49.67 b
H_2V_3	5.07 b	5.35 b	10.42 b	48.69 b
H_3V_1	4.65 c	5.40 b	10.05 bc	46.27 bc
H_3V_2	5.65 a	5.40 b	11.05 a	51.13 a
H_3V_3	5.25 ab	5.35 b	10.60 b	49.53 b
LSD $_{(0.05)}$	0.06	0.15	0.22	0.63
CV (%)	9.79	6.91	10.26	7.90

In a column, means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly as per 0.05 level of probability
H_0 – Control, H_1 – Pyrazosulfuron ethyl 70% WG @ 15 g ha^{-1}, H_2 – Bensulfuron methyl 10% WP @ 50 g ha^{-1} and H_3 – Metsulfuron methyl 20% WP @ 20 g ha^{-1}
V_1 – BRRI dhan38, V_2 – BRRI dhan70 and V_3 – BRRI dhan80

4.2.12.3 Interaction effect of herbicidal weed control and variety

The straw yield (t ha^{-1}) varied significantly due to different weed control and varietal treatment combinations (Table 12 and Appendix VII). The highest straw yield (5.70 t ha^{-1}) was obtained from the combination of control (no herbicide used, no weeding) with BRRI dhan38 (H_0V_1). The lowest (4.95 t ha^{-1}) was found from the combination of Pyrazosulfuron ethyl 70% WG @ 15 g ha^{-1} with BRRI dhan70 (H_1V_2). This result was similar to the findings of Salam *et al.* (2010) who stated that the highest straw yield (7.37 t ha^{-1}) was found due to application of

Machete 5G @ 25 kg ha^{-1} in *boro* rice (BINA dhan5). Similar results were also observed by Hassan *et al.* (2010).

4.2.13 Biological yield (t ha^{-1})

4.2.13.1 Effect of herbicidal weed control

The biological yield (t ha^{-1}) varied significantly due to different weed control treatments (Table 10 and Appendix VII). Weeds controlled by Metsulfuron methyl 20% WP @ 20 g ha^{-1} (H_3) gave the highest biological yield (10.57 t ha^{-1}). Control (H_0, no herbicide used, no weeding) treatment gave the lowest biological yield (9.55 t ha^{-1}) which was statistically similar with Pyrozosulfuran ethyl 70% WG @ 15 g ha^{-1} (9.70). Similar results were also observed by Hossen (2014). Variations of biological yield among the treatment were dependent upon the severity of weed infestation thus affected grain yield and straw yield. Ahmed *et al.* (1998) reported that grain and straw yield (biological yield) decreased with increasing weed population and weed competition duration that partially supported the present experimental result.

4.2.13.2 Effect of variety

The biological yield (t ha^{-1}) varied significantly due to variety (Table 11 and Appendix VII). It was observed that BRRI dhan70 (V_2) produced significantly highest biological yield (10.44 t ha^{-1}) and the lowest biological yield (9.43 t ha^{-1}) was recorded from BRRI dhan38 (V_1). Similar results were also observed by Hossen (2014) and Chowdhury (2012).

4.2.13.3 Interaction effect of herbicidal weed control and variety

Biological yield (t ha^{-1}) was significantly affected by the interaction of different weed control and varietal treatment combinations in aromatic rice (Table 12 and Appendix VII). The highest biological yield (11.05 t ha^{-1}) was obtained from the combination of Metsulfuron methyl 20% WP @ 20 g ha^{-1} with BRRI dhan70 (H_3V_2). The lowest biological yield (8.77 t ha^{-1}) was found from the combination of control (no herbicide used, no weeding) with BRRI dhan38 (H_0V_1). This result

was similar to the findings of Salam *et al.* (2010) who stated that the highest grain yield (7.15 t ha^{-1}) and straw yield (7.37 t ha^{-1}) were found due to application of Machete 5G @ 25 kg ha^{-1}.

4.2.14 Harvest Index (%)

4.2.14.1 Effect of herbicidal weed control

Harvest index (%) of rice varied significantly due to the application of different herbicides in the aromatic rice field (Table 10 and Appendix VII). The maximum harvest index (48.98 %) was recorded from H_3 (Metsulfuron methyl 20% WP @ 20 g ha^{-1}) treatment. On the other hand, the minimum harvest index (41.93 %) was obtained from H_0(control, no herbicide used, no weeding) treatment. These findings are further supported with the work of Al-Mamun *et al.* (2011) and Bhuiyan *et al.* (2011), who obtained better yields in rice with herbicide use. Similar findings were observed by Manish *et al.* (2006) who stated that weeding had significant variation on harvest index.

4.2.14.2 Effect of variety

Variety showed significant variation in harvest index (Table 11 and Appendix VII). BRRI dhan70 (V_2) showed the highest harvest index (49.81 %) whereas lowest harvest index (42.24 %) in BRRI dhan38 (V_1). Similar results were also observed by Hossen (2014) and Chowdhury (2012).

4.2.14.3 Interaction effect of herbicidal weed control and variety

Interaction effect of weed control and variety showed significant variation in harvest index of rice (Table 12). The highest harvest index (51.13 %) was observed from the interaction effect of Metsulfuron methyl 20% WP @ 20 g ha^{-1} with BRRI dhan70 (H_3V_2). The lowest harvest index (35.00 %) was obtained from the interaction of control (no herbicide used, no weeding) with BRRI dhan38 (H_0V_1).

CHAPTER V

SUMMARY AND CONCLUSION

A field experiment was conducted at the Agronomy field, Sher-e-Bangla Agricultural University (SAU), during July to December, 2018 with view to finding out the performance of modern aromatic *aman* rice as affected by the herbicidal weed control method. The experiment was laid out in a split plot design with three replications. The size of the individual plot was 4 m x 2.5 m and total numbers of plots were 36. There were 12 treatment combinations. Herbicidal weed control was placed along the main plot and Variety in the sub plot. Weed control methods *viz.*, H_0 – Control (No herbicide used, no weeding), H_1 – Pyrazosulfuron ethyl 70% WG @ 15 g ha^{-1}, H_2 – Bensulfuron methyl 10% WP @ 50 g ha-1 and H_3 – Metsulfuron methyl 20% WP @ 20 g ha-1 was applied at 5 DAT in 4-5 cm standing water for 3-5 days. 30 days old seedlings of V_1 - BRRI dhan38, V_2 - BRRI dhan70 and V_3 - BRRI dhan80 were transplanted on the well puddled experimental plots on 29 July, 2018 by using two seedlings $hill^{-1}$.

The data on weed parameters were collected from the 45 DAT. Weed parameters such as diversity of infested weed species, weed density (Number m^{-2}), dry matter content of weed (%) and weed control efficiency (%) were examined. The data on growth parameters *viz.*, plant height (cm), number of effective tillers $hill^{-1}$, number of non-effective tillers $hill^{-1}$, total number of tillers $hill^{-1}$ were recorded during the period from the harvesting time. At harvest, characters like panicle length (cm), number of filled grains $panicle^{-1}$, number of unfilled grains $panicle^{-1}$, total number of grains $panicle^{-1}$, 1000-grains weight (g), sterility (%), grain yield (t ha^{-1}), straw yield (t ha^{-1}), biological yield (t ha^{-1}) and harvest index (%) were recorded.

The twenty-five weed species infested the total experimental field which belongs to twelve families. The most important weeds of the experimental plots were *Cyperus michelianus, Echinochloa crussgalli, Marsilea crenata, Sagittaria guyanensis, Alternanthera sessilis, Cyperus difformis, Cyperus esculentus* and

Ludwigia octovalvis, respectively. Weed density, dry matter content of weed and weed control efficiency were significantly influenced by the weed control treatments. The highest weed density and dry matter content of weed were observed in the control (no herbicide used, no weeding) treatment. The lowest weed density and dry matter content of weed were found in the Metsulfuron methyl treatment. Weed density, dry matter content of weed and weed control efficiency were significantly influenced by the varietal treatments. The highest weed density and dry matter content of weed were observed in the BRRI dhan80 (13.32) treatment. The lowest weed density and dry matter content of weed were found in the BRRI dhan70 (9.98) treatment was at par with BRRI dhan38 (11.59).

Different weed control treatments with varietal combination had significant effect on crop growth parameters *viz*., plant height (cm), number of effective tillers hill^{-1}, number of non-effective tillers hill^{-1}, total number of tillers hill^{-1} at harvesting time. The highest plant height was observed in Metsulfuron methyl 20% WP @ 20 g ha^{-1} and BRRI dhan38 (128.10 cm). The highest effective tillers hill^{-1} and total tillers hill^{-1} was observed in Metsulfuron methyl 20% WP @ 20 g ha^{-1} and BRRI dhan70 (H_3V_2) 16.80 and 18.06, respectively.

Weed control treatments had significant effect on the yield and yield contributing characters *viz.*, panicle length, number of filled grains panicle^{-1}, 1000-grains weight, grain yield, biological yield and harvest index was highest in Metsulfuron methyl 20% WP @ 20 g ha-1with BRRI dhan70 (H_3V_2) treatment 34.81 cm, 98.46, 26.97 g, 5.65 t ha^{-1}, 11.05 t ha^{-1} and 51.13%, respectively and straw yield (5.70 t ha^{-1}) was highest in control with BRRI dhan38 (H_0V_1) treatment. The maximum sterility was observed in Bensulfuron methyl and BRRI dhan80 (18.95 %).

Based on the results of the present experiment, the following conclusion can be drawn:

1. Sedge weeds dominated the crop field throughout the growing period with the highest relative weed density in the study area.

2. Weed control method played a vital role for the growth and yield of aromatic *aman* rice.

3. Among the weed control treatment, Metsulfuron methyl 20% WP @ 20 g ha^{-1} was found the best for controlling weeds.

4. BRRI dhan70 produced highest grain yield (5.21 t ha^{-1}), biological yield (10.44 t ha^{-1}) and harvest index (49.81 %).

5. Metsulfuron methyl 20% WP @ 20 g ha^{-1} with BRRI dhan70 gave the highest grain yield (5.65 t ha^{-1}), biological yield (11.05 t ha^{-1}) and harvest index (51.13 %) due to highest dry matter production throughout the growing period.

However, to reach a specific conclusion and recommendation, more research work on modern and traditional variety and different weed control method with different doses should be done over different Agro-ecological zones of the country.

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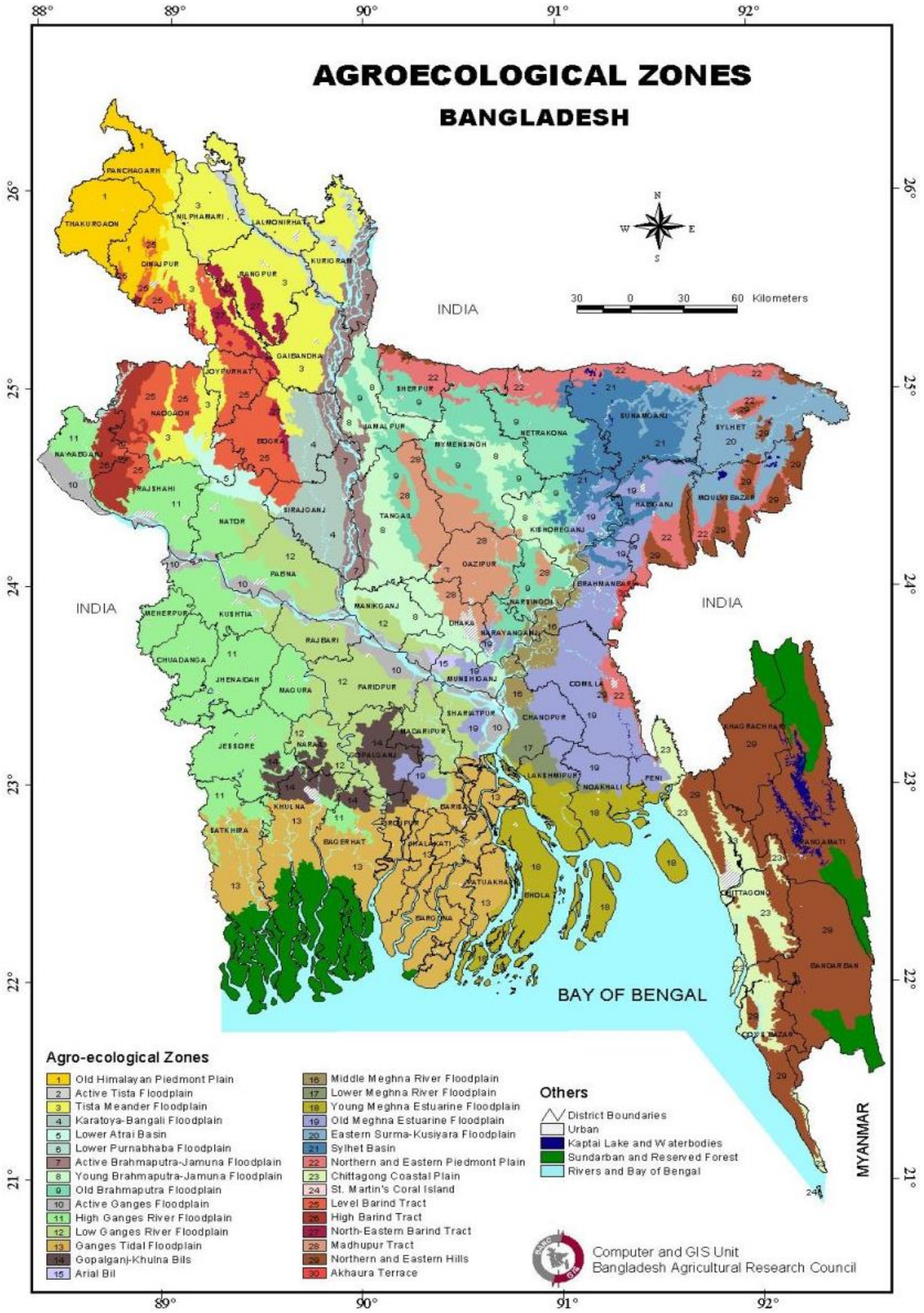
APPENDICES

Appendix I: Map showing the experimental sites under study



Appendix II: Characteristics of Agronomy Farm soil is analyzed by Soil Resources Development Institute (SRDI), Khamarbari, Farmgate, Dhaka

Morphological characteristics of the experimental field

Morphological features	Characteristics
Location	Agronomy Ferm, SAU, Dhaka
AEZ	Madhupur Tract (28)
General Soil Type	Shallow red brown terrace soil
Land type	High land
Soil series	Tejgaon
Topography	Fairly leveled
Flood level	Above flood level
Drainage	Well drained
Cropping Pattern	Boro rice-Fallow-Aman rice

A. Physical properties of the initial soil

Characteristics	Value
% Sand	27
% Silt	43
% clay	30

B. Chemical properties of the initial soil

Characteristics	Value
Textural class	Silty-clay
pH	5.6
Organic carbon (%)	0.45
Organic matter (%)	0.78
Total N (%)	0.077
Available P (ppm)	20.00
Exchangeable K (mel 100 g soil)	0.10
Available S (ppm)	45

Source: Soil Resource Development Institute (SRDI), Farmgate, Dhaka

Appendix III: Monthly average temperature, relative humidity and total rainfall of the experimental site during the period from July, 2018 to December, 2018

Year	Month	Air Temperature (°C)			Relative Humidity (%)	Total Rainfall (mm)	Total Sunshine (hour)
		Maximum (°C)	Minimum (°C)	Mean (°C)			
2018	July	33	27	30	76	884.07	268
	August	34	27	30	76	1,739.92	302
	September	34	27	30	71	1,026.24	292.5
	October	33	26	30	59	264.00	238
	November	33	25	29	51	49.20	210.5
	December	28	20	25	51	103.40	206

Source: Bangladesh Metrological Department (Climate and weather division), Agargaon, Dhaka

Appendix IV: Analysis of variance of data on weed density (number m^{-2}), dry matter content of weed (%) and weed control efficiency (%)

Source of variation	Df	Weed density (Number m^{-2})	Dry matter content of weed (%)	Weed control efficiency (%)
Replication	2	0.37	0.36	4.087
Herbicide (A)	3	215.38*	40.10*	9023.399*
Error	6	0.008	0.004	1.865
Variety (B)	2	66.00*	52.52*	132.601*
A × B	6	4.06**	0.21**	20.370*
Error	16	0.007	0.007	2.421

*Significant at 5% level of probability

** Significant at 1% level of probability

Appendix V: Analysis of variance of data on plant height (cm), No. of Effective Tiller Hill^{-1}, No. of Non-Effective Tiller Hill^{-1} and No. of Total Tiller Hill^{-1}

Source of variation	Df	Plant height	Effective tiller	Non-effective	Total tiller
Replication	2	578.16	0.11	0.03	0.25
Herbicide (A)	3	80.57*	28.70*	3.29*	29.17*
Error	6	4.28	0.002	0.001	0.002
Variety (B)	2	193.45**	31.52*	3.96*	21.16**
A × B	6	0.18*	4.47*	0.13**	4.91*
Error	16	2.02	0.002	0.001	0.003

*Significant at 5% level of probability
** Significant at 1% level of probability

Appendix VI: Analysis of variance of data on panicle length (cm), Number of filled grains panice^{-1}, Number of unfilled grains panice^{-1}, Number of total grains panicle^{-1}, Sterility (%) and 1000-seeds weight (g)

Source of variation	df	Panicle length	Filled Grain panicle^{-1}	Unfilled grain panicle^{-1}	Total grains	1000-grain weight	Sterility
Replication	2	0.89	2.77	0.44	0.022	0.44	0.130
Herbicide (A)	3	17.47**	398.11*	14.88*	193.686*	23.89*	52.364*
Error	6	0.16	5.06	0.006	0.003	0.009	0.054
Variety (B)	2	197.98*	407.02*	51.50*	254.875*	131.17*	183.818*
A × B	6	1.08*	33.41*	0.20**	283.741*	0.72**	19.951*
Error	16	0.12	2.11	0.009	0.007	0.008	0.010

*Significant at 5% level of probability
** Significant at 1% level of probability

Appendix VII: Analysis of variance of data on grain yield (t/ha), straw yield (t/ha), biological yield (t/ha) and harvest Index (%)

Source of variation	Df	Grain yield	Straw yield	Biological yield	Harvest Index
Replication	2	0.004	0.010	0.027	0.012
Herbicide (A)	3	2.566**	0.159**	3.437**	66.940*
Error	6	0.001	0.010	0.012	0.228
Variety (B)	2	4.404**	0.168**	4.356**	148.040*
A × B	6	0.092**	0.254**	0.143**	18.687*
Error	16	0.001	0.010	0.016	0.174

*Significant at 5% level of probability
** Significant at 1% level of probability

LIST OF PLATES

Plate 1: Field view of experimental plot

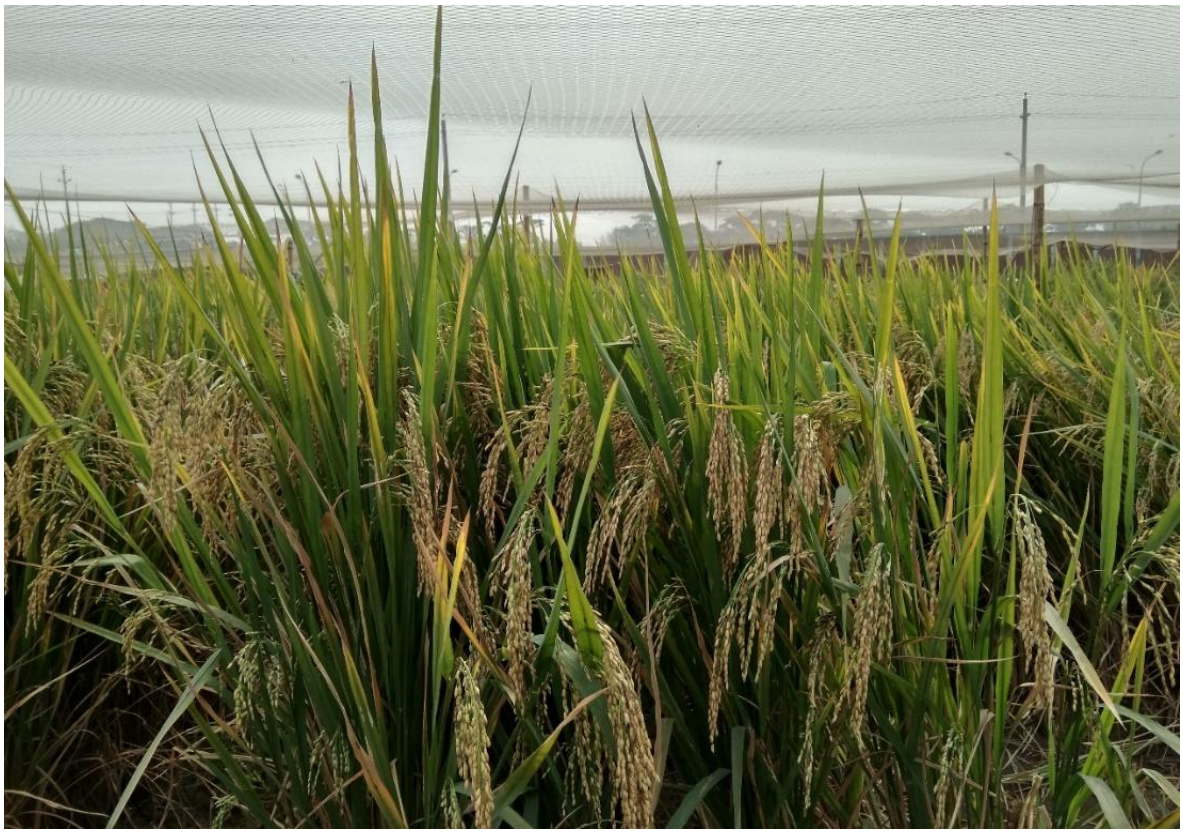


Plate 2: Field view of ripening stage

Chadmala ***(Sagittaria guyanensis)***

Khetpapri ***(Lindernia procumbens)***

Bara shama ***(Echinicola crussgsli)***

Chanchi ***(Alternanthera sesillis)***

Plate 3(a): Major weeds in the experimental plot

Jhilmorich *(Sphenoclea zeylanica)*

Choto shama *(Echinochola colonum)*

Chapra *(Elusine indica)*

Nakful *(Cyperus michelianus)*

Plate 3(b): Major weeds in the experimental plot

Shusni shak *(Marsilea crenata)*

Panilong *(Ludwigia octovalvis)*

Moyurleza *(Leptochloa panicea)*

Matichaise *(Fimbristylis miliacea)*

Plate 3(c): Major weeds in the experimental plot